individual ecological receptors (e.g., compared to ecologically based screening levels). However, results of INL Site biotic sampling conducted as part of INL Site environmental monitoring programs were used to assess transport of contaminants from subsurface to surface soil, to locations outside the SDA, and into the food web.

E-1.1.4.8 Nature and Extent of Contamination—Conclusions. Evaluation of the nature and extent of contamination concludes that low concentrations of carbon tetrachloride are affecting the aquifer near the SDA. Carbon tetrachloride has been detected slightly above the MCL, but concentrations appear to be leveling off, which may be the result of vapor vacuum extraction by the Organic Contamination in the Vadose Zone Project (i.e., Operable Unit-7-08).

Several other contaminants buried in the SDA have been detected at low concentrations in the vadose zone and may be migrating. Most vadose zone detections are in the interval above the B-C interbed. Highest densities were detected in the vadose zone beneath Pit 5 and Pad A and in the western end of the SDA. The most frequently detected contaminants in the vadose zone are VOCs, uranium isotopes, nitrate, Tc-99, and C-14. In addition, Sr-90, Cl-36, Pu-238, Am-241, I-129, and Pu-239/240 have been detected sporadically at concentrations near detection limits.

The monitoring network has been greatly expanded since 1998, with the addition of more than 300 probes in the waste, 62 vadose zone lysimeters, five upgradient aquifer wells, and an aquifer monitoring well inside the SDA. Additional vapor ports also have been installed, bringing the total to 212, 174 of which are sampled routinely. Concentrations in the environment around the SDA will continue to change over time due to several factors. Examples include:

- Remedial actions at the SDA could affect concentrations in the environment (e.g., beryllium block grouting will reduce C-14 concentrations in the vadose zone)
- Continued operation of the Operable Unit 7-08 vapor vacuum extraction and treatment system removes VOCs from the vadose zone
- Subsidence repairs and surface contouring reduce migration by decreasing the amount of infiltration through the waste and into the subsurface
- Degradation of waste packages also influences measured concentrations (e.g., as containers fail over time, more contamination is available for transport to the surface by plants and animals or into the subsurface with infiltration).

E-1.1.5 Summary of Section 5—Contaminant Fate and Transport

Section 5 addresses modeling of contaminant source release, potential routes of contaminant migration and persistence for the subsurface pathway, and methodology for determining rate constants used in the biotic model. Complete exposure pathways defined by the conceptual site model led to three types of models: source release, subsurface transport, and biotic transport. Persistence of contaminants in the environment was evaluated based on contaminant mobility controlled by dissolved-phase transport, vapor-phase transport, and biotic transport by animals and plants intruding into the waste.

Modeling presented in Section 5 uses best-estimate inventories as the basis for analyzing baseline risk in Section 6. These models also will be used to support remedial decisions for Operable Unit 7-13/14 by simulating long-term effectiveness of various remedial actions. Many aspects of the source-release and groundwater pathway modeling have been improved compared to the ABRA model. However, uncertainties are and always will be associated with predicting movement of contaminants; therefore, conservatism is retained in the modeling and is demonstrated through comparison to monitoring. The primary improvement over the ABRA model is incorporation of additional information into the source-release model regarding inventory, waste streams, and disposal locations within the SDA. These improvements and results from additional characterization have been incorporated into the source-release model and its interface with the vadose zone model. Improvements also have been made in groundwater pathway modeling; however, those improvements have had less impact on predicted concentrations. For groundwater pathway modeling, the primary improvements were updating the VOC modeling and including gaseous-phase C-14 transport.

Eighteen source areas were defined for implementation in the source-release model (see Figure E-6). The source-term model simulated release of contaminants into the subsurface from buried waste. The DUST-MS code[a] (Sullivan 1992) was used to simulate release of contaminants of potential concern and their long-lived decay-chain products. Simulated mass-release mechanisms comprised surface washoff, diffusion, and dissolution. Release mechanisms were identified based on waste-stream-specific data. Output from the source-release model provided input to both the biotic-transport and subsurface-transport models.

Fate and transport of both dissolved-phase and vapor-phase contaminants in the SDA subsurface were modeled with the three-dimensional TETRAD simulator (Shook 1995). Beginning with contaminant fluxes received as input from the source-release model, the TETRAD model simulates movement of contaminants in the vadose zone down to the aquifer and subsequent aquifer transport. Figure E-7 shows three-dimensional views of the vadose zone base grid and the first- and second-level grid refinements. Simulations produced estimates of future contaminant concentrations in groundwater. The model was parameterized in consultation with modeling staff from DEQ and EPA, as reflected in values presented in the Second Addendum to the Work Plan (Holdren and Broomfield 2004). Site-specific data describing lithology, spatially variable infiltration, sorption, and other characteristics were applied, where available. Contaminant transport in the aquifer was simulated until peak aquifer concentrations were achieved or to a maximum of 10,000 years. Sensitivity cases were modeled to evaluate effects of upper-bound inventories and additional selected parameters on estimated media concentrations and risk.

The DOSTOMAN code was used to estimate surface soil concentrations produced by biotic transport of contaminants to the surface by plants and animals. Rate constants and other input parameters used in the code (e.g., rooting depths) were selected from current literature, giving preference to site-specific values for the SDA and the INL Site, when available. The biotic model was not calibrated because surface soil at the SDA is routinely redistributed through contouring and operations and because of the fundamental assumption that remedial action at the SDA will include a surface barrier (Holdren and Broomfield 2004). The DOSTOMAN model soil concentrations were estimated for the current timeframe and for future human health and ecological exposure scenarios.

Sensitivity simulations showed that source inventory and the type of mass-release mechanism (i.e., surface washoff, diffusion, and dissolution) have the largest impact on predicted contaminant concentrations in environmental media. The amount of infiltration through the waste and the low-permeability region in the aquifer are two other model features that significantly affect predicted groundwater concentrations. The amount of water that contacts waste influences groundwater pathway concentrations. Water is the driving force that moves aqueous-phase contaminants along the groundwater pathway. Sensitivity simulations show that additional water in the vadose zone, which does not contact waste, primarily dilutes groundwater pathway concentrations. The low-permeability region in the aquifer also substantially impacts predicted concentrations by reducing dilution that would otherwise occur, thus

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a. References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with the INL Site.

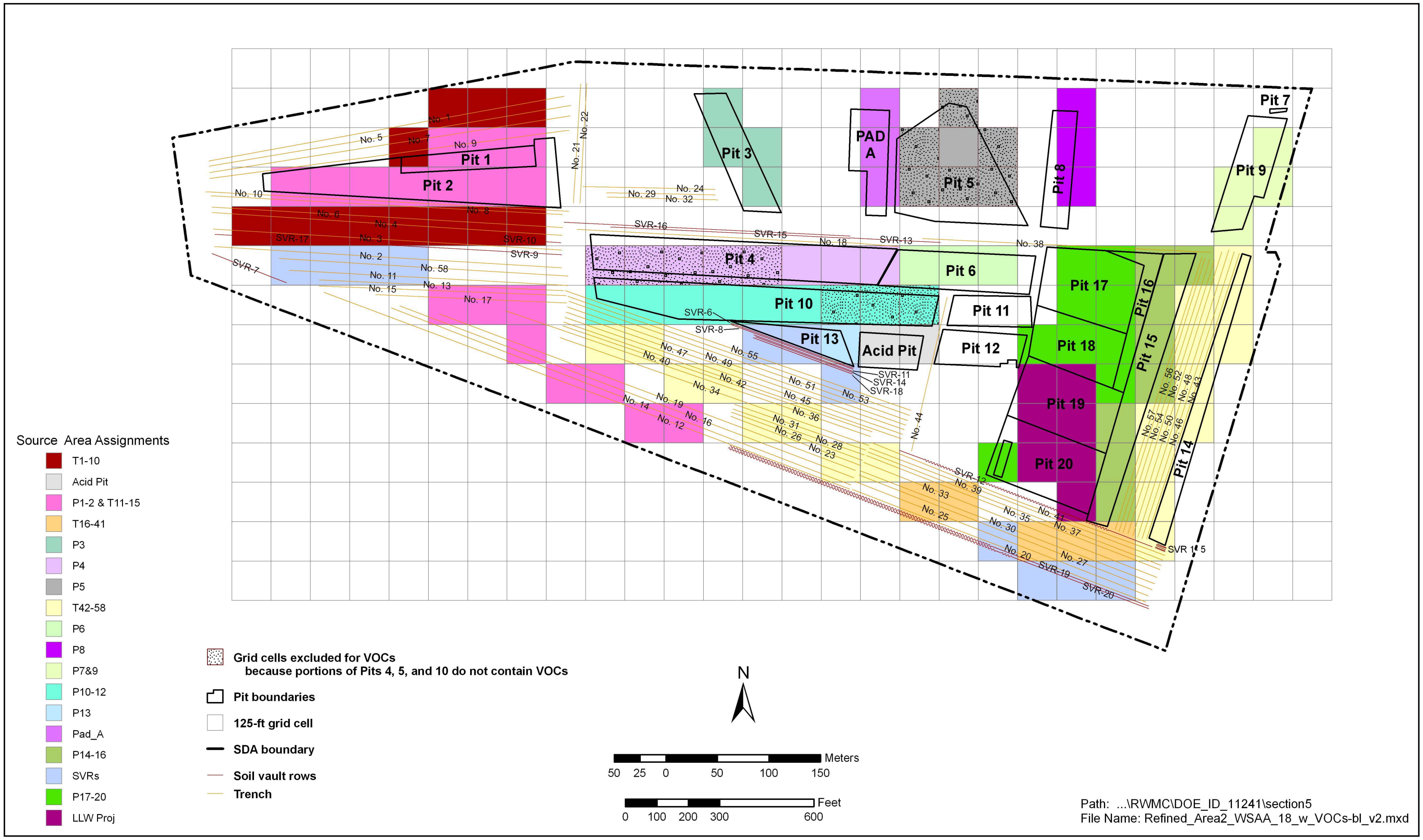


Figure E-6. Eighteen source areas simulated in the source-release model.

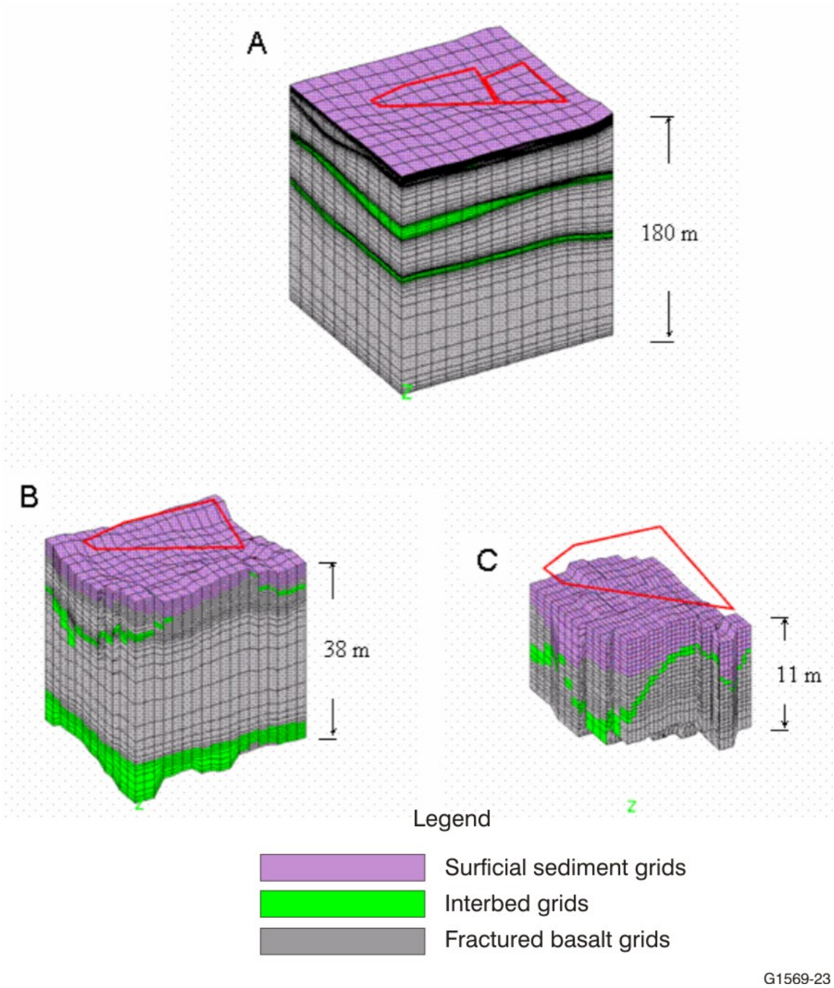
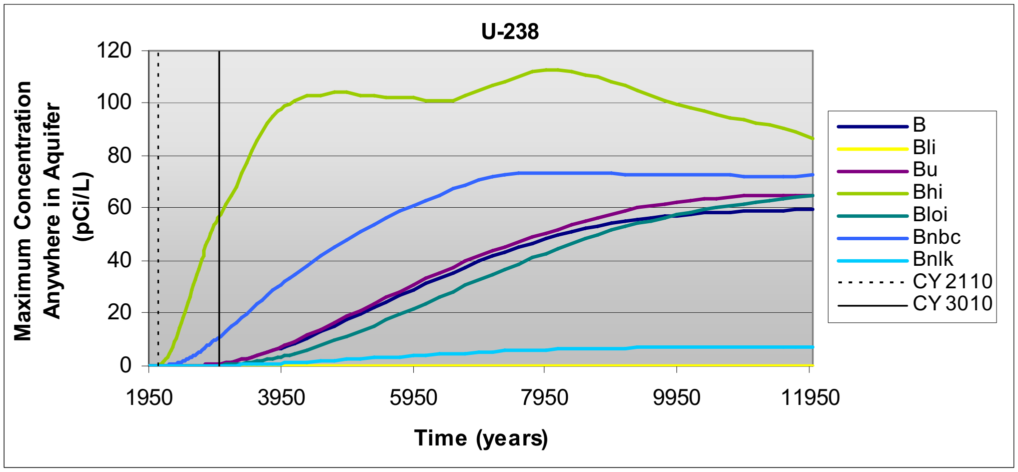


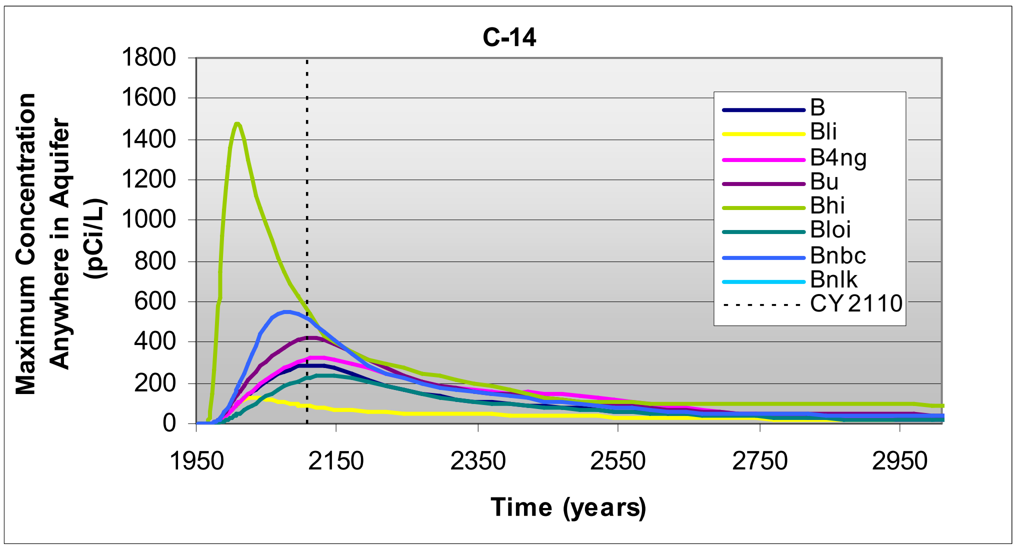
Figure E-7. Southwest views of base grid (A), first-level refined grid (B), and second-level refined grid (C) beneath the Subsurface Disposal Area showing vertical conformable gridding. The A-B interbed appears black in the base grid as a result of fine vertical discretization.

preserving higher concentrations that reflect concentrations influxing from the vadose zone. Figure E-8 compares results from various sensitivity simulations for U-238 (a long-lived actinide), C-14 (a dual-phase radionuclide), and nitrate (a dissolved-phase nonradionuclide). Maximum concentrations anywhere in the aquifer are presented to facilitate comparison between various sensitivity simulations. The different simulations are identified using the following nomenclature:

- B = Baseline risk assessment
- Bli = Baseline risk assessment with low infiltration inside the SDA
- B4ng = Baseline risk assessment with no retrieval and no beryllium block grouting
- Bu = Baseline risk assessment with upper-bound inventory
- Bhi = Baseline risk assessment with high infiltration inside the SDA
- Bloi = Baseline risk assessment with low background infiltration outside the SDA
- Bnbc = Baseline risk assessment with no B-C interbed

Bnlk = Baseline risk assessment with no low-permeability region.





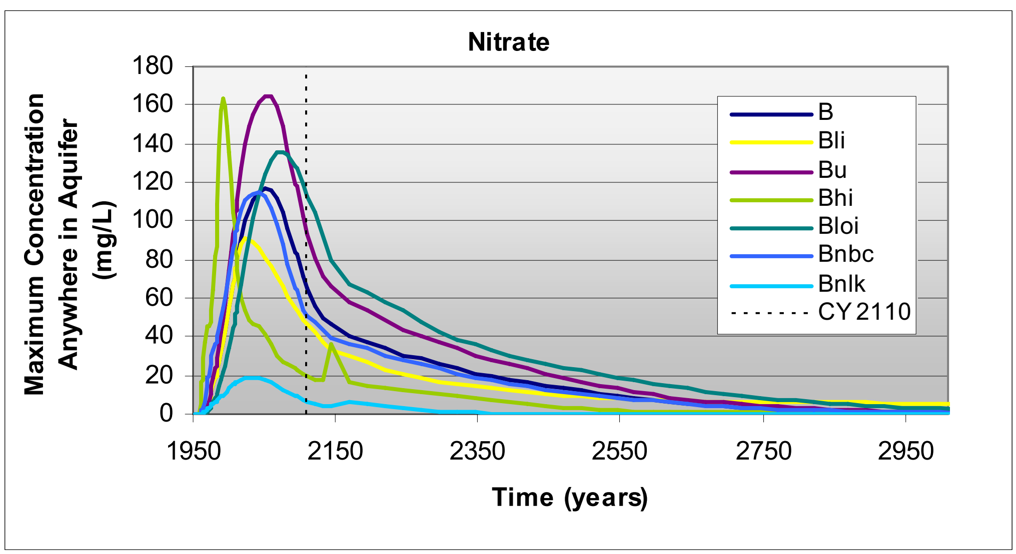


Figure E-8. Combined sensitivity results for maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate.

Best judgment was used to select parameters for the source-release model and the subsurface flow and transport model. Fortunately, from an environmental consequence perspective, movement of contaminants in the vadose zone and aquifer beneath the SDA is slow, and no extensive dissolved-phase contaminant plume is available against which to calibrate. An extensive database exists for contaminants in the waste zone, unsaturated zone, perched groundwater (when and where present), and regional aquifer, but there is no clear general pattern of contaminant detections nor trends in concentrations at this time, except for the volatile contaminants. Results of source-release and dissolved-phase subsurface flow and transport models can be compared only to the presence or absence of contaminants in field monitoring data instead of calibration to a contaminant plume. The ongoing monitoring program and evaluation of monitoring results are time consuming and expensive. Results of these monitoring activities have shown promise in identifying trends in contaminant behavior that are useful for determining the relative conservatism in modeling.

Limited calibration to vapor-phase carbon tetrachloride was achieved. Particular parameters were adjusted within reasonable uncertainty ranges until model results adequately agreed with observations of carbon tetrachloride in vadose zone soil-gas and aqueous concentrations in the aquifer. The goal of calibration was to match observed general trends and not be overly concerned with matching values at specific points. This goal was achieved. Limited calibration also was achieved in representing spatial distribution of observed soil-water matric potentials in the B-C and C-D interbeds, where wetter conditions are consistently observed within SDA boundaries compared to locations outside the SDA fence.

Personnel from DOE, DEQ, and EPA consider model results a reasonable basis for estimating potential risk to human health and the environment and for assessing appropriate remedial alternatives to mitigate unacceptable risk. However, results must be considered in light of uncertainties associated with this analysis. Modeling results (i.e., simulated concentrations) are consistently overpredicted in the aquifer (i.e., neglecting sporadic detections), overpredicted at some vadose zone monitoring locations, and underpredicted at other vadose zone monitoring locations. In general, groundwater pathway modeling results are conservative. This conservatism primarily results from (1) overestimating contaminant source release, (2) including rapid vertical transport in the fractured basalt portions of the vadose zone, and (3) including the extensive low-permeability region in the aquifer domain, which limits dilution. Because the model overpredicts current concentrations in the aquifer, it is certain that model results are conservative at present. The amount of uncertainty in the predictive results undoubtedly increases with time, decreasing the level of confidence that the model remains reasonably conservative over time. Monitoring over time and comparing monitoring results against model predictions will be an important aspect of post-record of decision monitoring.

E-1.1.6 Summary of Section 6—Baseline Risk Assessment

Human health and ecological risk assessments in Section 6 are based on simulated concentrations of contaminants in environmental media developed through numerical modeling (see Section E-1.1.5). Potential threats to human health and the environment, in the absence of any remedial action, are evaluated. The following subsections provide a synopsis of general approaches and results of human health and ecological risk assessments.

E-1.1.6.1 Human Health Baseline Risk Assessment. Building on earlier results in the IRA and the ABRA, Section 6 addresses potential risk to human health from contaminants buried in the SDA. Based on EPA and INL guidance (EPA 1988, 1989; Burns 1995), Waste Area Group 7 was comprehensively assessed by evaluating cumulative, simultaneous risk for all complete exposure pathways for all contaminants of potential concern. The risk assessment included exposure and toxicity assessments, risk characterization, parametric sensitivity analysis, and qualitative evaluation of uncertainty. Contaminant screening for the RI/BRA identified 33 human health contaminants of potential concern for quantitative evaluation: 27 radionuclides, five VOCs, and one inorganic chemical. Risk estimates were developed for occupational and residential scenarios for complete exposure pathways identified in the conceptual site model (see Figure E-9).

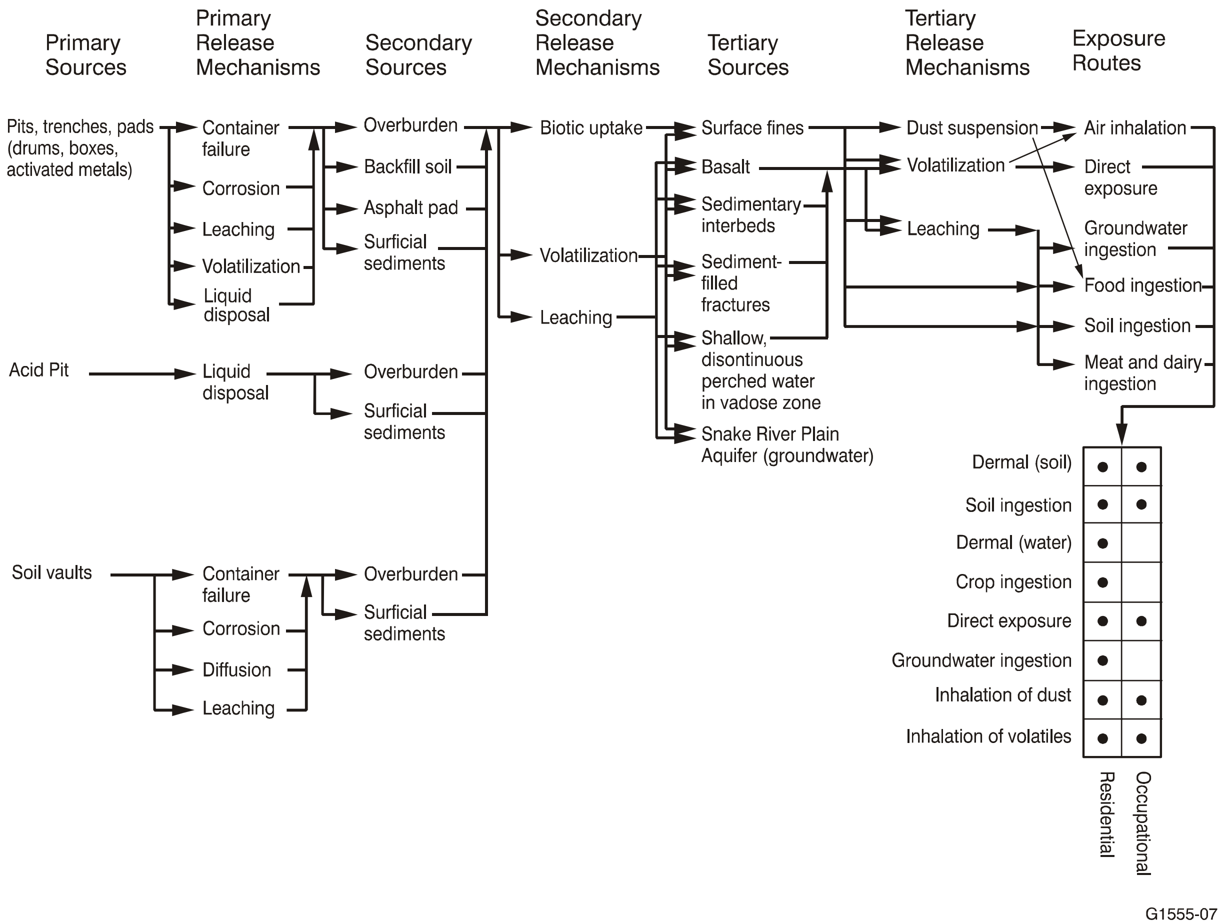


Figure E-9. Human health conceptual site model.

E-1.1.6.1.1 Occupational Scenarios—Evaluation of a current occupational scenario yielded risk estimates exceeding 1E-06; therefore, future occupational risks also were assessed as required in the Second Addendum (Holdren and Broomfield 2004). Risk estimates exceed 1E-06 for Sr-90 and carbon tetrachloride for the current occupational scenario. However, risk reaches maximum values for both contaminants within the 100-year current occupational scenario timeframe; therefore, though the future occupational scenario was assessed, results do not add important conclusions to risk characterization.

E-1.1.6.1.2 Residential Scenarios—For the current residential scenario, groundwater ingestion risk at the nearest downgradient INL Site boundary was assessed. Surface exposure pathways were not examined for a current residential exposure because residential development near RWMC is prohibited by site access restrictions. Cumulative risk for the current residential scenario is approximately 1E-06.

Future residential exposures were simulated, beginning in the year 2110, following an assumed 100-year institutional control period. Future residential analysis reflects land-use projections and the assumption that institutional controls would preclude direct access into the waste, but that a location immediately adjacent to RWMC could be inhabited. The future residential scenario bounds the risk, meaning that risk estimates are higher than for all other exposure scenarios. Concentrations and risks were simulated out to 1,000 years for all pathways except groundwater ingestion. Groundwater risks were simulated until concentrations peaked or to a maximum of 10,000 years.

For residential scenarios, 18 contaminants within the 1,000-year simulation period have cumulative risk greater than or equal to 1E-05, a hazard index greater than or equal to 1, or simulated groundwater concentrations that exceed MCLs. Residential risk estimates are greater than or equal to 1E-05, or simulated groundwater concentrations are greater than MCLs for eight additional contaminants within the 10,000-year simulation period.

In the 1,000-year simulation period, highest residential risks are driven by biotic uptake and surface pathway exposure from Am-241, Cs-137, Pb-210, Pu-239, Pu-240, Ra-226, Ra-228, Sr-90, Th-228, and trichloroethylene. Risks from I-129, 1,4-dioxane, and nitrate are primarily through groundwater pathway exposures; risks from C-14 and carbon tetrachloride are primarily through groundwater and vapor inhalation (at the surface) exposures, while Tc-99 risk is primarily through groundwater ingestion and irrigating crops with groundwater. Simulated groundwater concentrations for the 1,000-year simulation period exceed MCLs immediately adjacent to the SDA for I-129, Tc-99, carbon tetrachloride, 1,4-dioxane, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene.

Figure E-10 shows total risk over time and relative contributions attributable to each exposure pathway for the future residential scenario immediately adjacent to the SDA. Except for inhalation of volatiles, risk remains greater than 1E-05 for each exposure pathway throughout the 1,000-year simulation period, and cumulative risk remains well above 1E-03. External exposure and soil ingestion dominate the risk. Crop ingestion risk is initially higher than soil ingestion risk immediately after institutional control. Inhalation risk is less than 1E-05 immediately after institutional control but increases rapidly. Volatile inhalation risk is slightly greater than 1E-05 at the end of institutional control but decreases to less than 1E-05 within 50 years. Figures E-11 through E-15 illustrate individual pathway risks for surface exposure pathways over 1,000 years. Each figure shows the total by pathway, major contributors to the total, and the sum of other contaminants.

Figure E-16 shows total 1,000-year groundwater ingestion risk for all radionuclides and nonradionuclides, major contributors to the total, and the sum of other contaminants. Groundwater ingestion risk immediately after the end of institutional control is driven by carbon tetrachloride and Tc-99. Within the 1,000-year simulation, eight contaminants exceed their respective MCLs: I-129, Tc-99, carbon tetrachloride, 1,4-dioxane, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene. Results for Tc-99 and I-129, particularly for groundwater exposure pathways, are highly uncertain because simulated concentrations in the vadose zone and aquifer are grossly inconsistent with monitoring data. As a consequence, groundwater risk attributable to these contaminants could be significantly misrepresented. For example, if actual release is very slow, initial risk (i.e., in the year 2110) would be substantially lower, perhaps less than 1E-05. Risk from slower release also would be incurred over a longer period. Conversely, the current simulations imply that risk is very high early in the simulation timeframe and diminishes over a few hundred years.

Groundwater simulations were extended to 10,000 years to evaluate long-lived radionuclides that did not achieve peak simulated concentrations in the 1,000-year simulations. Estimated risk is greater than or equal to 1E-05 for eight actinides: Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. Primary contributors are Np-237 and U-238. Concentrations exceed MCLs in the 10,000-year simulations for these same two actinides.

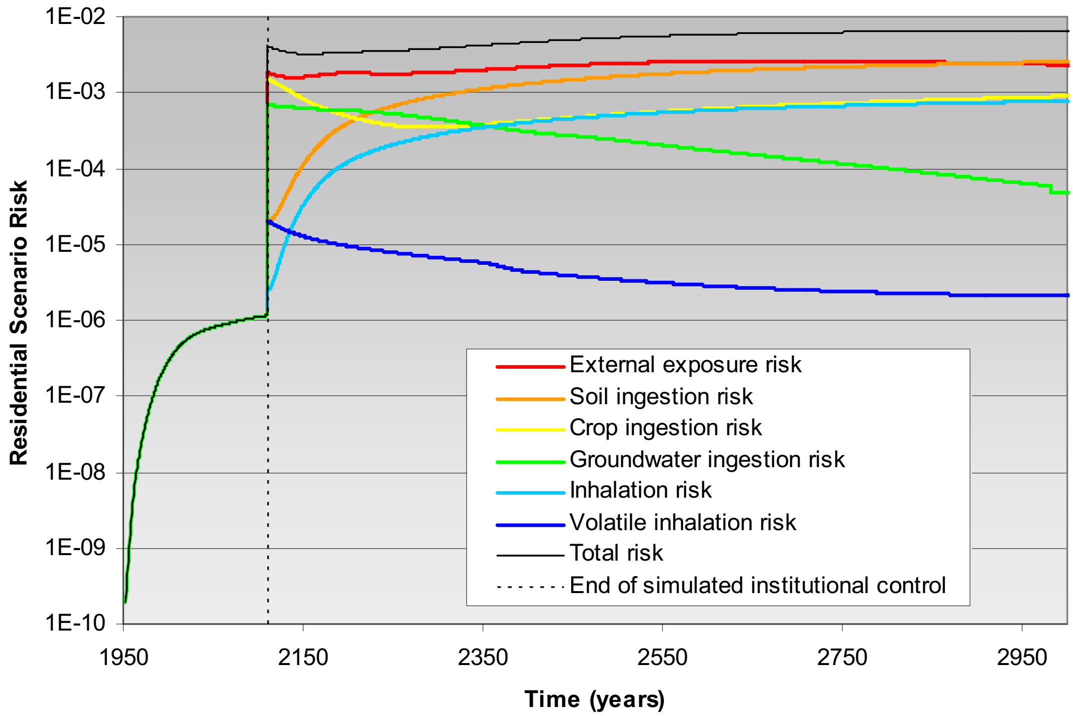


Figure E-10. Total residential exposure scenario risk by exposure pathway for all radionuclides and nonradionuclides.

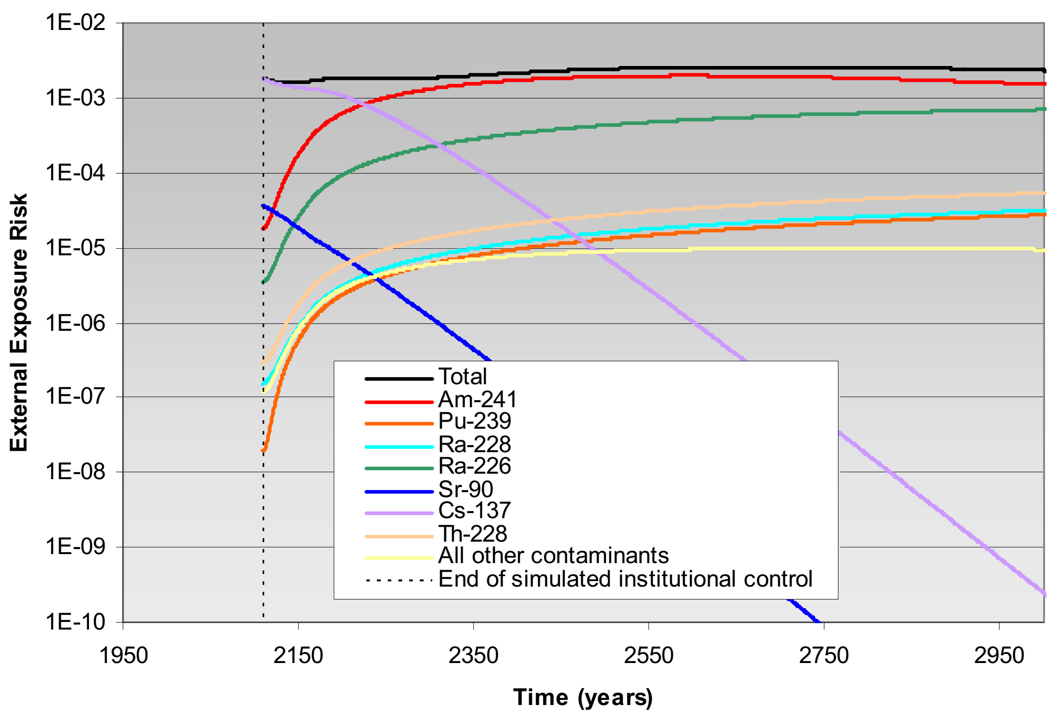


Figure E-11. Major contributors to external exposure risk.

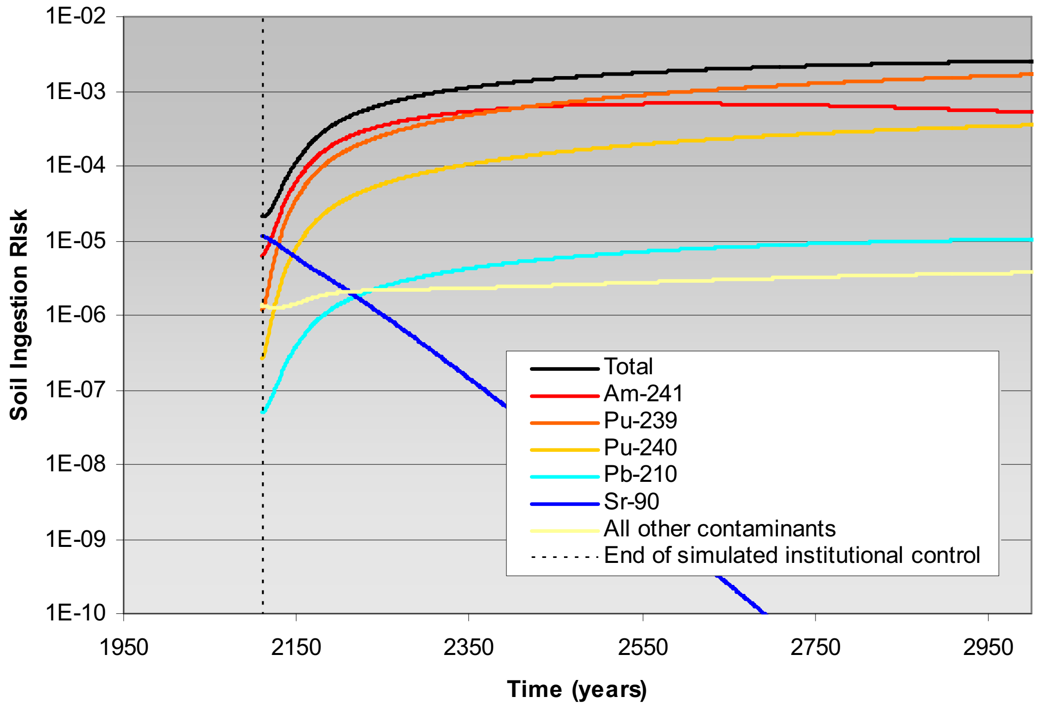


Figure E-12. Major contributors to soil ingestion risk.

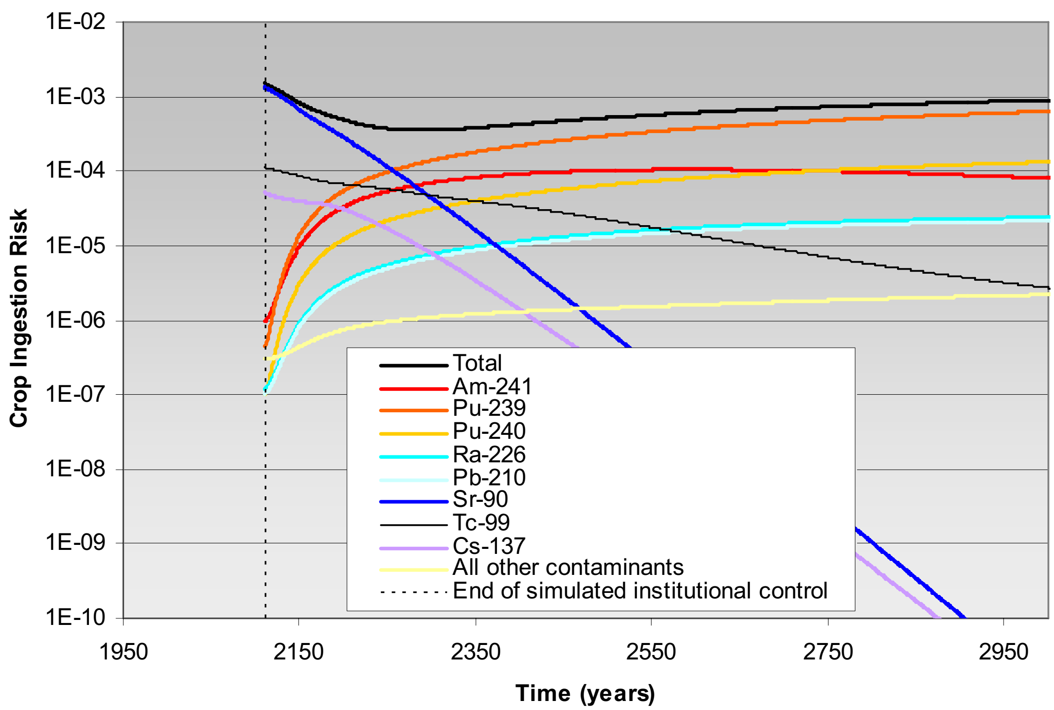


Figure E-13. Major contributors to crop ingestion risk.

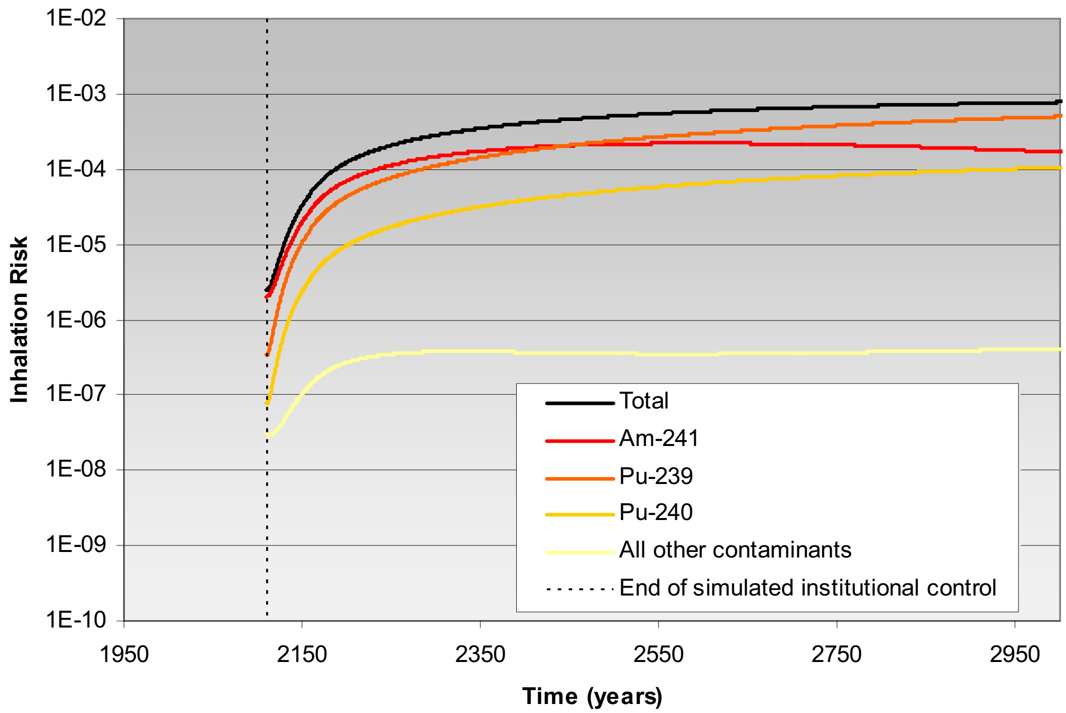


Figure E-14. Major contributors to inhalation risk.

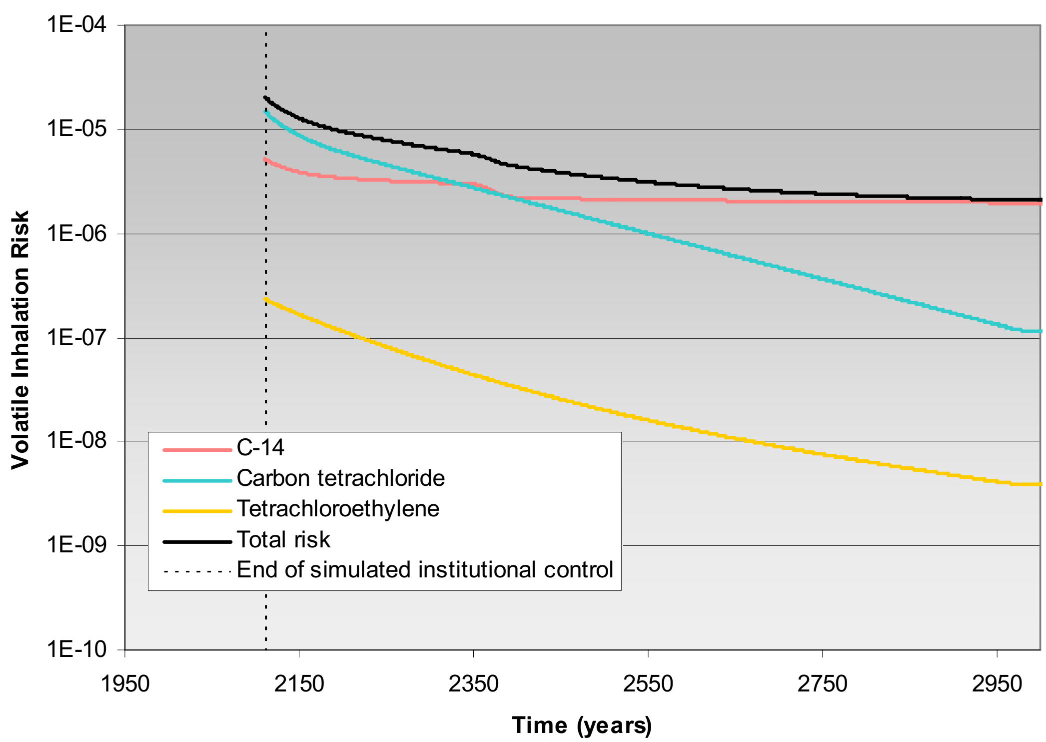


Figure E-15. Volatile inhalation risk by contaminant.

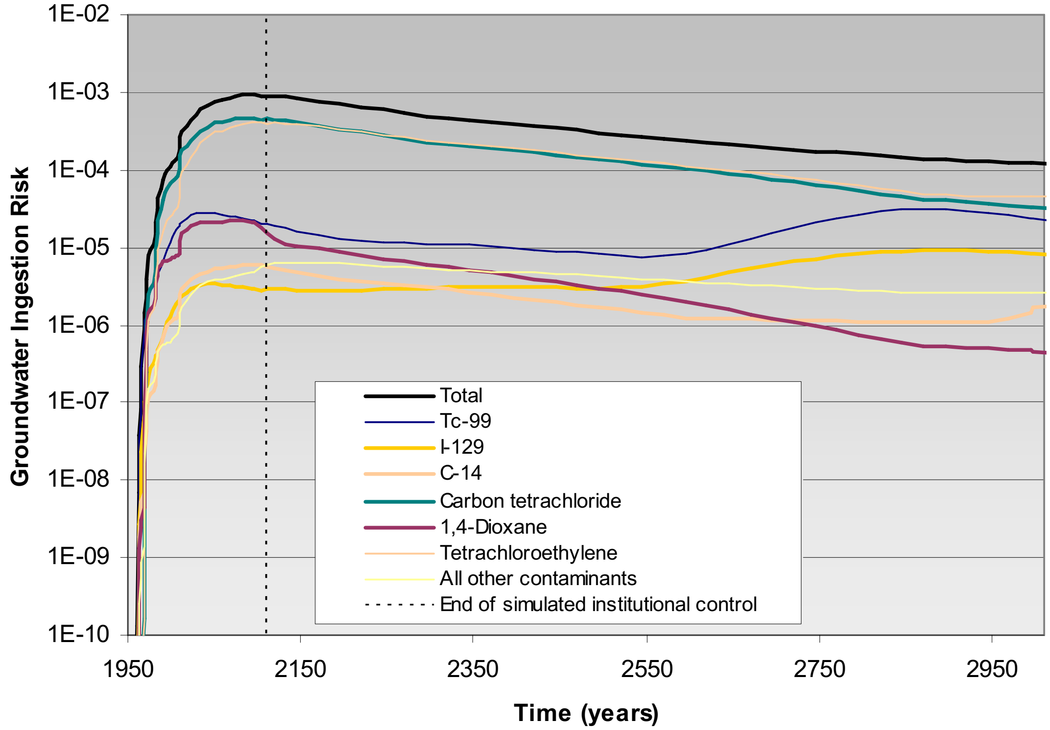


Figure E-16. Groundwater ingestion risk by contaminant.

E-1.1.6.1.3 Uncertainty—Parametric sensitivity and qualitative uncertainty analyses were performed for parameters identified by DOE, DEQ, and EPA as important for understanding uncertainty in base-case risk. The sensitivity analysis shows the effect on predicted risk of changes in selected model inputs. With the exception of inventory sensitivity, sensitivity analysis focused on the groundwater ingestion pathway. The following list summarizes sensitivity cases:

- **Inventory**—To assess sensitivity to source-term inventory, risk was estimated based on upper-bound inventories. Risk estimates for most contaminants were of the same order of magnitude, with total cumulative risk for all contaminants higher by an approximate factor of 2.

- **Infiltration**—Three sensitivity cases addressing infiltration rates were examined: (1) reduced background infiltration outside the SDA, (2) low infiltration inside the SDA, and (3) high uniform infiltration inside the SDA. Reduced background infiltration produced slightly higher risk estimates, while lower and higher infiltration inside the SDA paralleled lower and higher risk.

- **Interbed gaps—**The effect of neglecting known gaps in the B-C interbed was evaluated by completely eliminating the B-C interbed in the model; negligible effect was noted.

- **Pit 4 retrieval and beryllium block grouting—**Because the base case incorporated assumptions that beryllium blocks would be grouted and targeted retrieval in Pit 4 would be completed, a sensitivity case was performed to examine consequences of not completing these remedial actions. If beryllium blocks are not grouted, C-14 groundwater ingestion risk increases slightly. If the half-acre retrieval in Pit 4 is not completed, groundwater risk does not change. Except for carbon tetrachloride, Rocky Flats Plant contaminants do not drive groundwater risk. The retrieval area contains only a small fraction of the carbon tetrachloride.

- **Low-permeability zone—**Effects of the postulated low-permeability zone assumed for the base case were evaluated by implementing a sensitivity case that did not include such a region in the aquifer. In the absence of a low-permeability zone, risk estimates are substantially lower (e.g., decrease from 3E-04 to 4E-05 for radionuclides, excluding Tc-99 and I-129), further suggesting that base-case model results are conservative.

- **No sorption in interbeds—**Removing the effects of plutonium sorption in interbed sediment was evaluated by completely eliminating sorption in the B-C and C-D interbeds using an approach roughly equivalent to spreading the plutonium source term into a thin layer (i.e., by advective spreading in the vadose zone) and leaching it directly into the aquifer. Results of this extremely conservative simulation show several orders of magnitude increase in risk.

E-1.1.6.2 Inadvertent Intruder Analysis. The intrusion scenario in Section 6.6 evaluates acute risk to a hypothetical worker drilling an agricultural irrigation well after the institutional control period. Two locations in the SDA (i.e., a high-gamma area and a high-alpha area) were selected for evaluation, based on disposal records. Results show that the high-gamma location could pose a risk of 4E-04, largely from external exposure to Cs-137. For the high-alpha location, the total risk is 4E-07.

E-1.1.6.3 Ecological Risk Assessment. The ecological risk assessment in Section 6.7 was a screening-level analysis because of the fundamental assumption that the SDA will be covered with a surface barrier (DOE-ID 1998; Holdren and Broomfield 2004). Current and 100-year scenarios were evaluated for representative receptors. Contaminant screening focused evaluation on those contaminants most likely to pose unacceptable risk; 56 contaminants of potential concern were identified—16 radionuclides and 40 nonradionuclides. Concentrations in surface soil and subsurface intervals were estimated with the DOSTOMAN biotic uptake model. Receptor exposures were evaluated for all 16 Waste Area Group 7 radionuclides; eight of the 40 nonradionuclides were evaluated as indicators of potential risk. Thirteen contaminants, ten radionuclides (i.e., Am-241, Cs-137, Pu-238, Pu-239, Pu-240, Pu-241, Ra-226, Sr-90, U-234, and U-238), and three nonradionuclides (i.e., beryllium, cadmium, and lead) were shown to pose risk greater than threshold values to Waste Area Group 7 ecological receptors in both the current and future scenarios.

E-1.2 Conclusions of the Remedial Investigation and Baseline Risk Assessment

Conclusions based on this RI/BRA provide the foundation for subsequent analysis and ultimately will support risk management decisions for Operable Unit 7-13/14. The first subsection below reviews the approach applied by DOE, DEQ, and EPA to address uncertainties inherent in this RI/BRA. Results of the risk assessment and uncertainty associated with those results then are used to transition from the RI/BRA to the feasibility study. Contaminants of *potential* concern (i.e., those contaminants that *might* pose unacceptable risk if no remediation is implemented) are screened to identify contaminants of concern (COCs) (i.e., those contaminants that might require risk management decisions). Final subsections present recommendations for the feasibility study and reiterate remedial action objectives.

E-1.2.1 Basis for Conclusions—Overall Uncertainty in Modeling and Risk Assessment

Personnel from DOE, DEQ, and EPA have actively participated throughout development of the RI/BRA to produce a mathematical modeling approach useful for predicting release and transport of contaminants from waste buried in the SDA. The unchanging goal has been to develop a reasonably conservative model—one that is not excessively conservative (overpredicting concentrations) or excessively nonconservative (underpredicting concentrations). This is a difficult goal to achieve in any simulation, but even more difficult for Operable Unit 7-13/14 for several reasons, as described in the following subsections.

E-1.2.1.1 Inventory. The SDA is a landfill that has received thousands of shipments over the past five decades. Thousands of records have been researched extensively to verify source-term information for the SDA. Data have been compiled into a database that can query shipments. Though some shipment locations have been verified through probing into a few key areas, absolute certainty is not a practical objective for a 97-acre landfill (containing approximately 35 acres of waste) that has been in service since 1952. However, the database includes inventory estimates (mass or curies), an approximate location, and waste form descriptions for almost every shipment placed in the SDA. This information is used to fulfill modeling requirements for site characterization data. For instance, modeling requires information about inventories of contaminants and the physical form of the waste. Information must be developed to address the following: whether contaminants are in solution, whether they are sorbed into a matrix in bags inside barrels, whether barrels are carbon steel or stainless steel, whether waste is in boxes and whether boxes are wood or cardboard, and how contaminants release from waste and how fast.

E-1.2.1.2 Infiltration. Movement of dissolved-phase (aqueous) contaminants in the unsaturated zone is controlled by the amount of water moving through the sedimentary layers. Typically, contaminants are transported in the shallow vadose zone in pulses that correlate with precipitation. These pulses are not specifically modeled. This compromise in the temporal effects of water movement causes some uncertainty in the modeling but was acceptable to DOE, DEQ, and EPA because pulses generally dampen with depth and do not influence long-term simulation results at depth. Water movement through sedimentary features can be described by a nonlinear set of equations, which are computer intensive to solve because the hydraulic conductivity of the layers depends on the moisture content and other characteristics of the materials in the layer. Complexity of variably saturated water movement through fractured basalts is less well understood, but significant insight into this movement and confidence in the equivalent-porous continuum modeling approach was gained by successful inverse modeling of a large-scale infiltration test that was conducted near RWMC in support of the RI/FS.

E-1.2.1.3 Sorption. Transport in the vadose zone and aquifer also is controlled by the tendency of each contaminant to adsorb onto sedimentary interbeds and, to a much lesser degree, to fractures in basalt. These contaminants can exist in different forms (e.g., oxidation states) in the environment, which greatly affects sorption. Mineralogy of sedimentary interbeds varies laterally and vertically within each sedimentary feature. An attempt to characterize spatial variability using distribution coefficients measured on corehole samples was unsuccessful in identifying spatial correlation. Therefore, single average values must be used to represent sorption for each contaminant, increasing the uncertainty in modeling results. Site-specific values were applied for sediments, when available; otherwise, conservative values were selected. Sorption of contaminants conservatively was assumed to not occur with fractured basalts.

E-1.2.1.4 Calibration. Modeling efforts at the other INL Site facilities (e.g., Test Area North and Idaho Nuclear Technology and Engineering Center) were facilitated by the presence of contaminants in soil, perched water, or the aquifer from past releases. Characterization data describing spatial and temporal aspects of these releases and presence of plumes within the aquifer provided benchmarks for model development. Fate and transport models could be reasonably calibrated to these plumes. A similar approach could not be implemented for Operable Unit 7-13/14 because well-defined plumes, patterns of detection, and consistent trends in concentrations do not exist, except for VOCs. Simulations for dissolved-phase contaminants, therefore, can be compared only to the absence or presence of contaminants in monitoring. The model sometimes predicts the presence of contaminants in the unsaturated zone or in the regional aquifer when those contaminants have not been detected. This modeling effort, except for calibrated VOC modeling, is wholly predictive.

E-1.2.1.5 Simulation Periods. Because this modeling effort is wholly predictive (except for VOCs), the predictive nature of the modeling for 100-year timeframes (i.e., restoration timeframe) is uncertain, and the degree of uncertainty is much greater for the longer 1,000-year timeframes. This uncertainty was recognized and accepted by DOE, DEQ, and EPA in the context of developing risk management decisions for Operable Unit 7-13/14. Extending groundwater simulations to 10,000 years was identified as necessary to assess potential long-term risk to human health and the environment because of the long-term presence and slow movement of some contaminants of concern. However, the level of uncertainty for these predictions is very large. These modeling predictions and the relative degree of uncertainty will be considered by DOE, DEQ, and EPA in developing risk management decisions.

E-1.2.2 Contaminants of Concern

Contaminants of concern are identified by reviewing human health risk estimates and simulated groundwater concentrations for contaminants of potential concern and applying screening criteria. Contaminants of concern are those individual contaminants that, when combined, cause cumulative risk to exceed threshold values. The EPA established a risk range from 10^{-4} to 10^{-6} for managing risk and expresses preference for the more protective end of the range (EPA 1991). The presence of multiple contaminants and exposure pathways (EPA 1989), land use projections (EPA 1995), and guidelines for risk management decisions (EPA 1997) also are important considerations in identifying COCs. Carcinogenic risk of 1E-04 and a hazard index of 1 for a future residential scenario are typical human health threshold values applied by DOE, DEQ, and EPA to support risk management decisions at the INL Site. Contaminants of concern then become the focus of an evaluation of remedial alternatives (i.e., a feasibility study) and, ultimately, risk management decisions.

Primary COCs for Operable Unit 7-13/14 are identified based on either of two screening criteria:

1. Contaminant has a total carcinogenic risk estimate greater than or equal to 1E-05 or a hazard index greater than or equal to 1 within the 1,000-year simulation period for the future residential exposure scenario. (The value of 1E-05 is used to identify COCs to ensure that additive carcinogenic risk from multiple contaminants remains less than the threshold of 1E-04.)

2. Simulated groundwater concentrations exceed the EPA MCLs within the 1,000-year simulation period.

Tables E-1 and E-2 identify radionuclide and nonradionuclide COCs, respectively, based on the above criteria. In total, 18 primary COCs are identified: 12 radionuclides and six nonradionuclides. Cumulative risk over time for all COCs is illustrated in Figure E-10 for the future residential scenario. Total cumulative risk for all contaminants is at a maximum of 7E-03 at the end of the 1,000-year simulation period in the year 3010. Surface exposure pathways contribute the most risk throughout the 1,000-year simulation period, with a maximum of 7E-03. As shown in Figures E-11 through E-15, the most significant contributors to surface pathway risk are Am-241, Cs-137, Pu-239, Sr-90, and carbon tetrachloride.

Table E-1. Primary radionuclide contaminants of concern based on 1,000-year future residential scenario peak risk estimates and groundwater concentrations.

Radionuclide	Peak Risk	Year	Primary Exposure Pathways[a]	Peak Aquifer Concentration (pCi/L)	Year	Maximum Contaminant Level (pCi/L)
Ac-227	5E-07	3010	Groundwater ingestion	5.30E-02	3010	15[b]
Am-241	3E-03	2594	External exposure, soil ingestion, inhalation, and crop ingestion	6.80E-08	3010	15[b]
Am-243	1E-07	3010	External exposure	1.29E-09	3010	15[b]
C-14	1E-05	2110	Groundwater ingestion and inhalation of volatiles (at the surface)	1.86E+02	2133	2,000
Cl-36	2E-06	2384	Groundwater ingestion and crop ingestion	2.12E+01	2395	700
Cs-137	2E-03	2110	External exposure and crop ingestion	NA	NA	NA
I-129	4E-05	2110	Groundwater ingestion	1.31E+01	2111[c]	1
Nb-94	2E-06	3010	External exposure	NA	NA	NA
Np-237	7E-06	2647	External exposure	6.53E-02	3010	15[b]
Pa-231	3E-07	3010	Groundwater ingestion	8.17E-02	3010	15[b]
Pb-210	3E-05	3010	Crop ingestion	1.02E-05	3010	NR
Pu-238	1E-06	2262	Soil ingestion, crop ingestion, and inhalation	6.10E-19	2920	15[b]
Pu-239	3E-03	3010	Soil ingestion, crop ingestion, and inhalation	5.19E-10	3010	15[b]
Pu-240	6E-04	3010	Soil ingestion, crop ingestion, and inhalation	1.28E-10	3010	15[b]
Ra-226	7E-04	3010	External exposure and crop ingestion	1.30E-05	3010	5
Ra-228	3E-05	3010	External exposure	1.97E-09	3010	5
Sr-90	1E-03	2110	Crop ingestion, external exposure, and soil ingestion	NA	NA	NA
Tc-99	3E-04	2110	Groundwater ingestion and crop ingestion (crops irrigated with contaminated groundwater)	2.71E+03	2111[c]	900
Th-228	5E-05	3010	External exposure	NA	NA	NA
Th-229	4E-07	3010	Groundwater ingestion	2.64E-02	3010	15[b]
Th-230	1E-08	3010	Crop ingestion, soil ingestion, and inhalation	3.01E-04	3010	15[b]
Th-232	3E-07	3010	Crop ingestion	2.82E-09	3010	15[b]
U-233	4E-06	3010	Groundwater ingestion	2.90E+00	3010	2.9E+05
U-234	6E-07	3010	Groundwater ingestion	3.97E-01	3010	1.87E+05
U-235	2E-07	2286	External exposure	1.19E-01	3010	6.49E+01
U-236	9E-07	3010	Groundwater ingestion	6.24E-01	3010	1.94E+03
U-238	1E-06	2285	External exposure	5.52E-01	3010	1.01E+01

a. All complete exposure pathways are assessed in the baseline risk assessment; those contributing most to risk are listed as primary exposure pathways. For COCs, all exposure pathways with risk greater than 1E-05 are listed from highest to lowest risk.
b. The limit is 15 pCi/L for total alpha (40 CFR 141).
c. Reported values are for the end of institutional control. The simulated peak occurs before the end of the 100-year institutional control period.
d. The limit is 3E-02 mg/L (30 µg/L) for total uranium. To compare concentrations of uranium isotopes, 3E-02 mg/L is converted to the equivalent activity for each isotope.

COC = contaminant of concern
MCL = maximum contaminant level
NR = not regulated

Surface exposure pathway COC	Groundwater pathway COC	COC for both surface exposure and groundwater pathways	COC based on potential to exceed MCL

Table E-2. Nonradionuclide contaminants of concern based on 1,000-year future residential scenario peak risk estimates and groundwater concentrations.

Contaminant	Peak Risk	Year	Peak Hazard Index	Year	Primary Exposure Pathways[a]	Peak Aquifer Concentration (mg/L)[b]	Year	Maximum Contaminant Level (mg/L)
Carbon tetrachloride	5E-04	2110	1E+01	2116	Inhalation of volatiles (at the surface) and groundwater ingestion	3.07E-01	2133	5.00E-03
1,4-Dioxane	2E-05	2110	NA	NA	Groundwater ingestion	1.69E-01	2111	3.00E-03[b]
Methylene chloride	5E-06	2244	3E-02	2244	Groundwater ingestion	5.85E-02	2245	5.00E-03
Nitrate	NA	NA	1E+00	2110	Groundwater ingestion	6.67E+01	2094[c]	10
Tetrachloroethylene	7E-07	2110	3E-01	2133	Groundwater ingestion	6.64E-02	2145	5.00E-03
Trichloroethylene	9E-04[d]	2110	NA	NA	Inhalation of volatiles (at the surface) and groundwater ingestion	3.80E-02[d]	2130	5.00E-03

a. All complete exposure pathways are assessed in the baseline risk assessment; those contributing most to risk are listed as primary exposure pathways. For COCs all exposure pathways with risk greater than 1E-05 or a hazard index greater than or equal to 1 are listed from highest to lowest risk.
b. No MCL is given, but a health advisory level is provided for reference.
c. The simulated nitrate peak occurs before the end of the 100-year institutional control period.
d. Trichloroethylene risk estimates and groundwater concentrations are based on scaling. Refined estimates will be developed in the feasibility study.

COC = contaminant of concern
MCL = maximum contaminant level

Surface exposure pathway COC	Groundwater pathway COC	COC for both surface exposure and groundwater pathways	COC based on potential to exceed MCL

Cumulative groundwater ingestion risk within the 1,000-year simulation period reaches a peak of 7E-04 at the end of the simulated institutional control period, when the location for the hypothetical residential receptor shifts from the INL Site boundary to the SDA boundary. Groundwater ingestion risk steadily diminishes over the 1,000-year simulation period (see Figure E-16). Cumulative groundwater ingestion risk isopleths are provided in Figures E-17, E-18, and E-19 for the 1,000-year residential scenario. In addition, groundwater ingestion hazard indexes of 1E+01 and 1E+00 are associated with carbon tetrachloride and nitrate, respectively. Maximum hazard index isopleths are shown in Figure E-20. Primary groundwater pathway risk drivers in the 1,000-year timeframe are carbon tetrachloride and Tc-99.

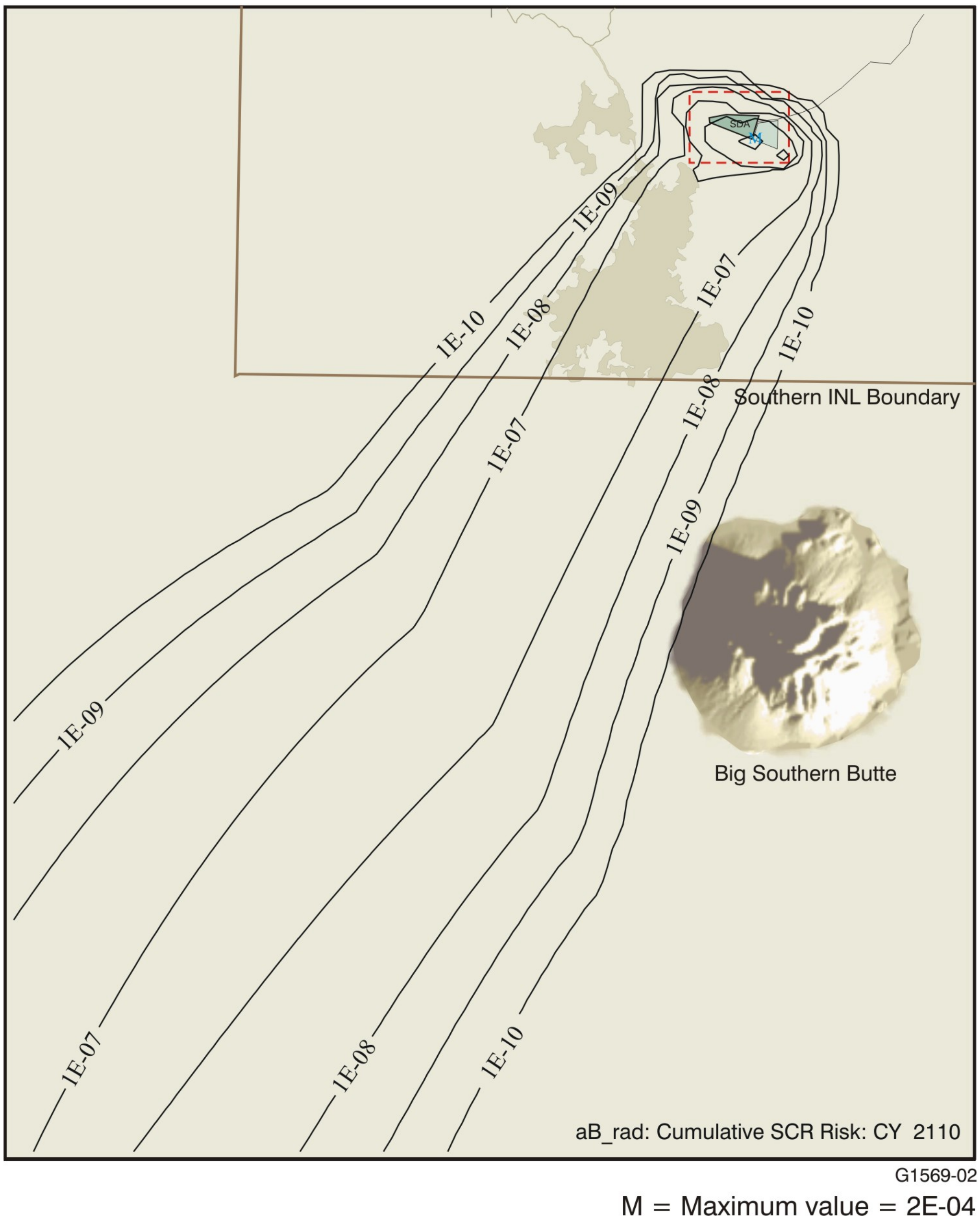


Figure E-17. Peak cumulative groundwater ingestion risk isopleths for radionuclides for the regional refined grid.

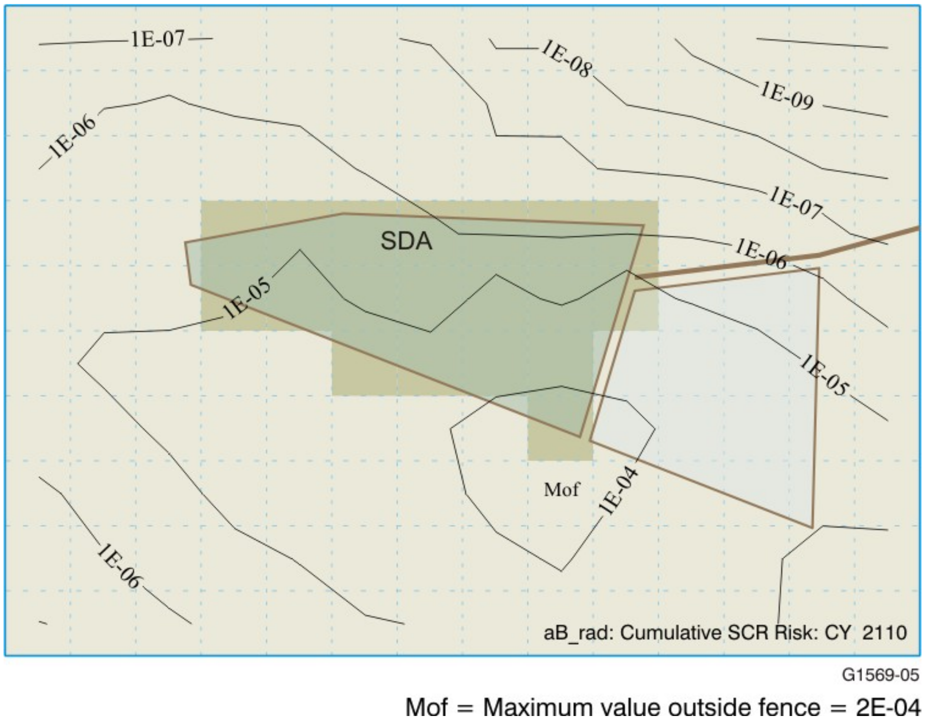


Figure E-18. Peak cumulative groundwater ingestion risk isopleths for radionuclides for the refined aquifer grid.

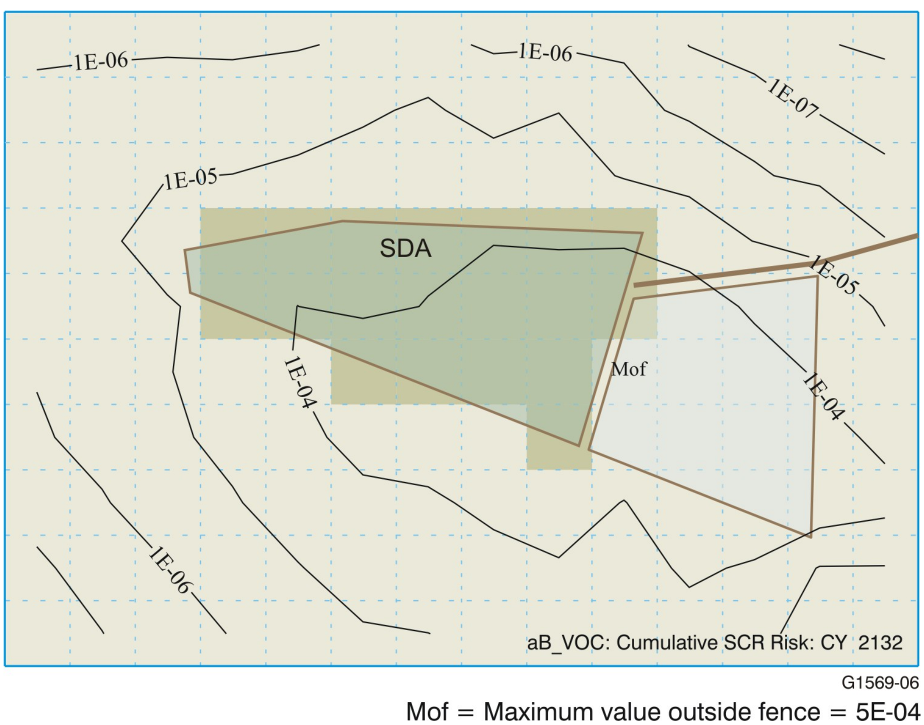


Figure E-19. Peak cumulative groundwater ingestion risk isopleths for volatile organic compounds.

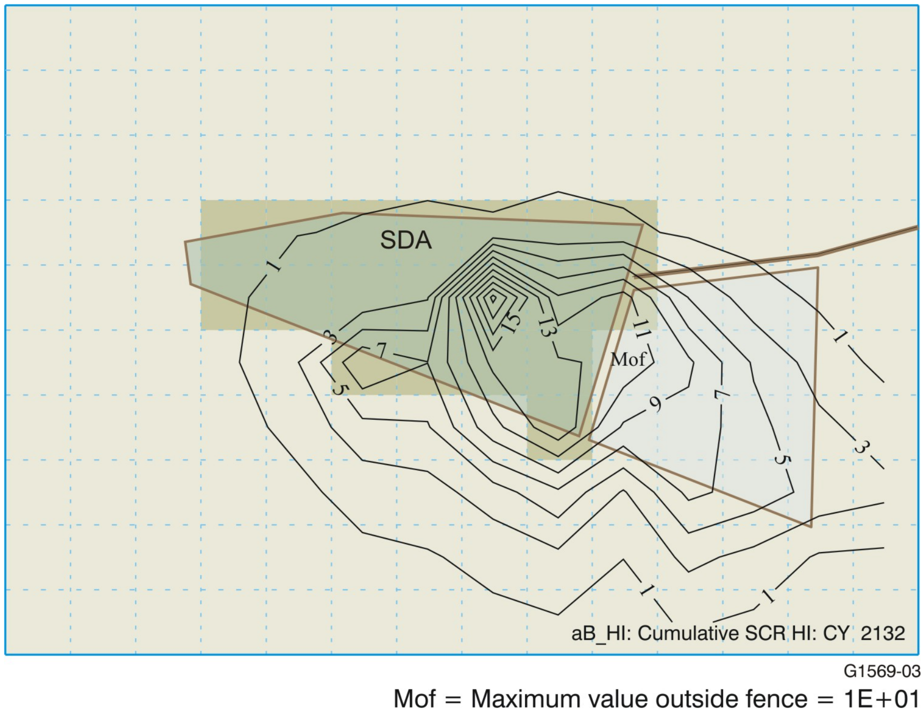


Figure E-20. Peak cumulative groundwater ingestion hazard index isopleths.

Risk estimates for Tc-99 and I-129 are highly uncertain because of gross inconsistencies between simulated and detected concentrations. Risks for Tc-99 and I-129 are likely overestimated, perhaps substantially. Figure E-21 shows groundwater ingestion risk with and without Tc-99 and I-129, illustrating upper-bound (represented by overestimated base case results) and lower-bound groundwater ingestion risk (represented by completely excluding Tc-99 and I-129). Actual risk is somewhere between these two extremes for Tc-99 and I-129. For comparison to Figure E-18, Figure E-22 shows groundwater risk isopleths without Tc-99 and I-129.

Simulated groundwater concentrations exceed MCLs (EPA 2000) within the 1,000-year simulation period for eight contaminants: two radionuclides and six nonradionuclides. Both radionuclides (i.e., I-129 and Tc-99) and four of the nonradionuclides (i.e., carbon tetrachloride, 1,4-dioxane, nitrate, and trichloroethylene) are identified as COCs because they exceed risk thresholds. Two additional COCs, methylene chloride and tetrachloroethylene, are identified solely on their potential to exceed their respective MCLs.

In total, 18 primary COCs are identified based on human health risk estimates or potential to exceed MCLs in the aquifer. Table E-3 identifies waste streams associated with these primary COCs. Several COCs (i.e., Pb-210, Ra-226, Ra-228, and Th-228) have very small initial inventories generated at the INL Site; however, risk is driven by inventories generated through ingrowth attributable to Rocky Flats Plant waste streams.

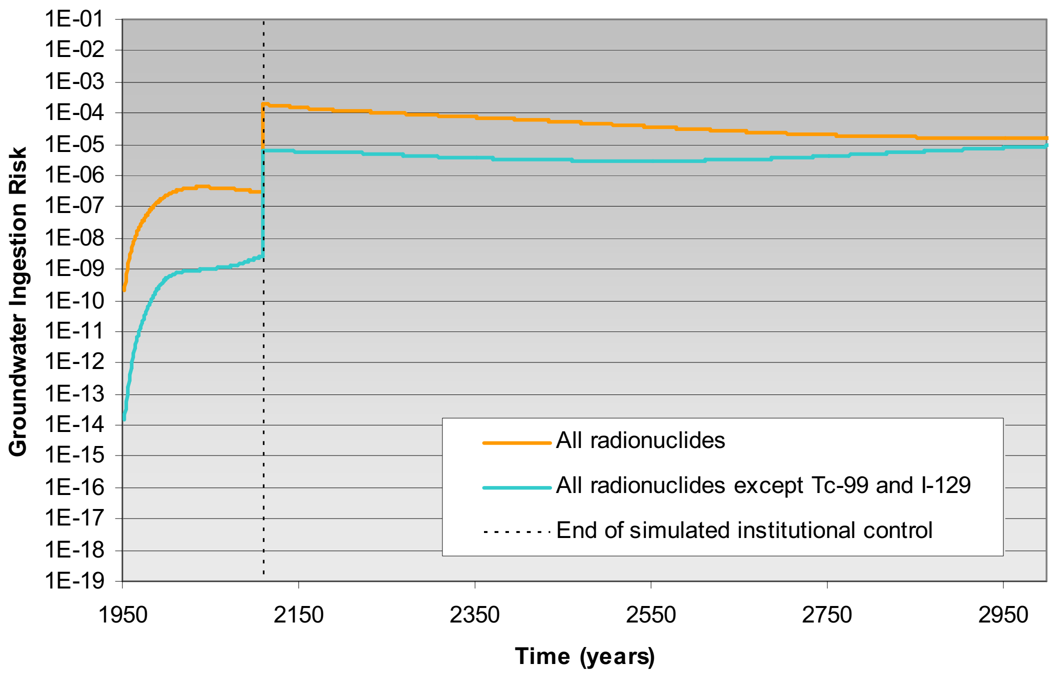


Figure E-21. Groundwater ingestion risk for radionuclides, including and excluding technetium-99 and iodine-129.

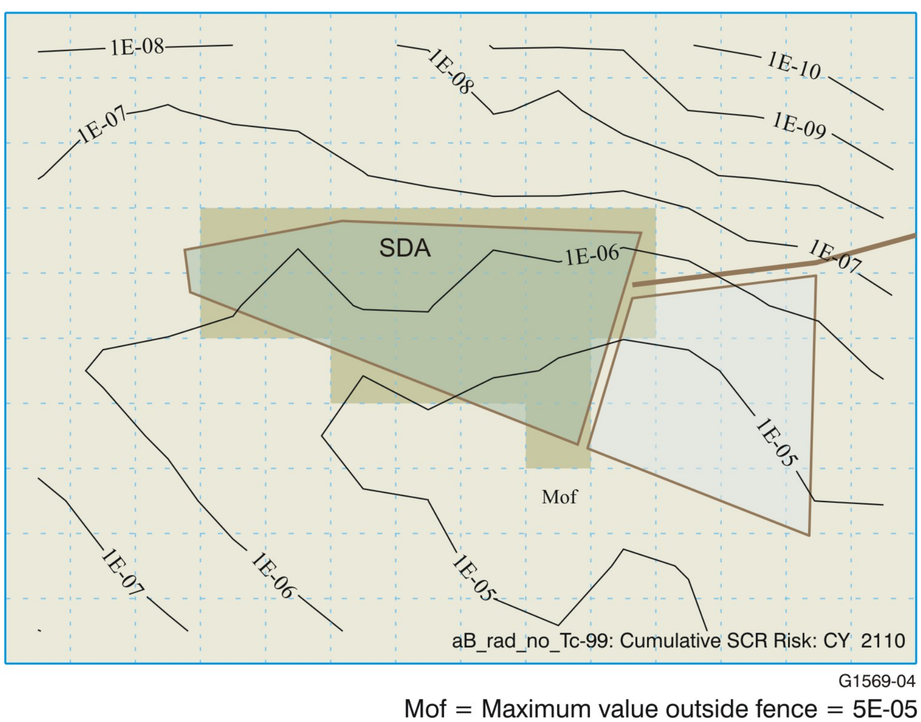


Figure E-22. Peak cumulative groundwater ingestion risk isopleths for radionuclides, excluding technetium-99, for comparison to Figure E-18.

Table E-3. Original waste generators and general locations of primary contaminants of concern in the Subsurface Disposal Area.

Contaminant	Waste Generator[a]	Portion (%)	Initial Inventory[b]	Areas of Highest Densities
Am-241	Rocky Flats Plant	100.0	2.43E+05	Pits
C-14	INL Site	100.0	7.31E+02	Trenches and soil vaults
Cs-137	INL Site	100.0	1.68E+05	Trenches and soil vaults
I-129	INL Site	100.0	1.88E-01	Trenches and soil vaults
Pb-210	Rocky Flats Plant	NA[c]	NA[c]	Pits
Pb-210	INL Site	100.0[c]	5.62E-07[c]	Trenches
Pu-238[d]	Rocky Flats Plant	88.7	1.85E+03	Pits
Pu-238[d]	INL Site	11.3	2.35E+02	Trenches
Pu-239	Rocky Flats Plant	98.3	6.30E+04	Pits
Pu-239	INL Site	1.7	1.08E+03	Trenches
Pu-240	Rocky Flats Plant	96.6	1.40E+04	Pits
Pu-240	INL Site	3.4	5.03E+02	Trenches
Ra-226	Rocky Flats Plant	NA[e]	NA[e]	Pits
Ra-226	INL Site	100.0[e]	6.53E+01[e]	Trenches
Ra-228	Rocky Flats Plant	NA[f]	NA[f]	Pits
Ra-228	INL Site	100.0[f]	3.66E-05[f]	Trenches
Sr-90	INL Site	100.0	1.36E+05	Trenches and soil vaults
Tc-99	INL Site	100.0	4.23E+01	Trenches and soil vaults
Th-228	Rocky Flats Plant	NA[g]	NA[g]	Pits
Th-228	INL Site	100.0[g]	1.05E+01[g]	Low-Level Waste Pit
Carbon tetrachloride	Rocky Flats Plant	100.0	7.90E+08	Pits
1,4-Dioxane	Rocky Flats Plant	96.0	1.87E+06	Pits (with carbon tetrachloride)
1,4-Dioxane	INL Site	4.0	4.24E+04	Pits, trenches, and soil vaults
Methylene chloride	Rocky Flats Plant	100.0	1.41E+07	Pits
Nitrate (as nitrogen)	Rocky Flats Plant	89.1	4.06E+08	Pits and Pad A
Nitrate (as nitrogen)	INL Site	10.9	4.98E+07	Pits
Tetrachloroethylene	Rocky Flats Plant	100.0	9.87E+07	Pits (with carbon tetrachloride)
Trichloroethylene	Rocky Flats Plant	99.6	8.92E+07	Pits (with carbon tetrachloride)
Trichloroethylene	INL Site	0.4	4.07E+05	Trenches

a. Portions listed for INL Site waste may include small amounts from off-INL Site waste generators, excluding Rocky Flats Plant.
b. Initial inventory at time of disposal; units are curies for radionuclides and grams for nonradionuclides.
c. Risk is attributable to ingrowth of Pb-210 from Pu-238 and U-238; initial disposal quantities are not significant.
d. Pu-238 is not, itself, a COC. However, Pu-238 decays to two COCs (i.e., Pb-210 and Ra-226).
e. Risk is attributable to ingrowth of Ra-226 from Pu-238 and U-238; initial disposal quantities are not significant.
f. Risk is attributable to ingrowth of Ra-228; initial disposal quantities are not significant. Ingrowth is primarily associated with Pu-240 from Rocky Flats Plant.
g. Risk is attributable to ingrowth of Th-228; initial disposal quantities are not significant. Ingrowth is primarily associated with Pu-240 from Rocky Flats Plant, though a small portion arises and then decays from U-232.

INL = Idaho National Laboratory

To address uncertainties associated with model results, simulations were extended to 10,000 years for long-lived radionuclides that did not reach peak simulated concentrations in 1,000-year simulations. Residential scenario risk estimates are greater than 1E-05 in the 10,000-year simulation period for eight radionuclides: Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. These eight radionuclides are identified as secondary COCs for the Operable Unit 7-13/14 feasibility study. Table E-4 lists secondary COCs. Figure E-23 shows groundwater ingestion risk for all eight radionuclides. Figures E-24 and E-25 show peak groundwater risk isopleths at the end of the 10,000-year simulation period for regional and local scales.

Table E-4. Secondary radionuclide contaminants of concern based on 10,000-year future residential scenario groundwater ingestion peak risk estimates and groundwater concentrations.

Radionuclide	Peak Risk	Calendar Year	Peak Aquifer Concentration	Maximum Contaminant Level
Ac-227	2E-05	12000	2.31E+00 pCi/L	15 pCi/L[a]
Np-237	1E-04	12000	8.68E+01 pCi/L	15 pCi/L[a]
Pa-231	1E-05	12000	3.20E+00 pCi/L	15 pCi/L[a]
U-233	2E-05	5352	1.30E+01 pCi/L	2.9E+05 pCi/L[b]
U-234	4E-05	12000	2.71E+01 pCi/L	1.87E+05 pCi/L[b]
U-235	1E-05	12000	7.18E+00 pCi/L	6.49E+01 pCi/L[b]
U-236	1E-05	12000	8.29E+00 pCi/L	1.94E+03 pCi/L[b]
U-238	9E-05	12000	4.71E+01 pCi/L	1.01E+01 pCi/L[b]
Total uranium[c]	NA	12000	1.44E-01 mg/L[c]	3.00E-02 mg/L[c]

a. The limit is 15 pCi/L for total alpha (40 CFR 141).
b. The limit is 3E-02 mg/L (30 µg/L) for total uranium. To compare concentrations of uranium isotopes, 3E-02 mg/L is converted to the equivalent activity for each isotope.
c. Total uranium is presented only for assessing simulated concentrations against the maximum contaminant limit. The peak concentration for total uranium is given in mg/L, developed by converting activity for each uranium isotope to mass and summing the results regardless of the timing of the peak. The maximum contaminant level is exceeded for total uranium, which is attributable almost completely to U-238.

Secondary contaminant of concern based on 10,000-year risk or concentration

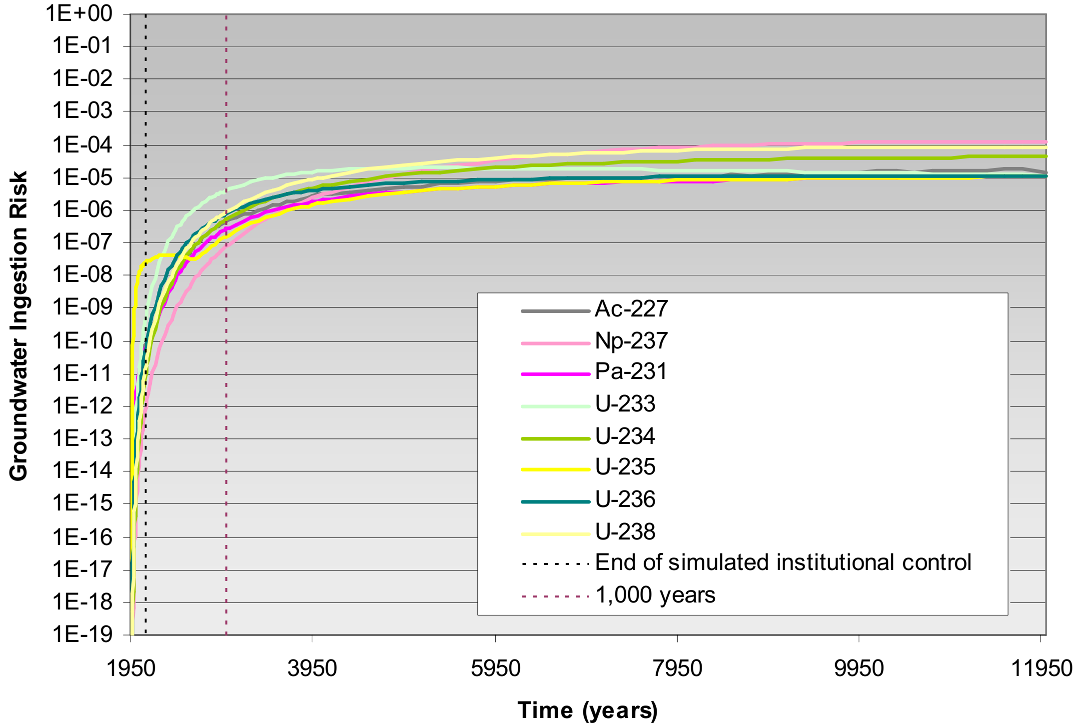


Figure E-23. Simulated 10,000-year groundwater ingestion risk for contaminants that peak after 1,000 years.

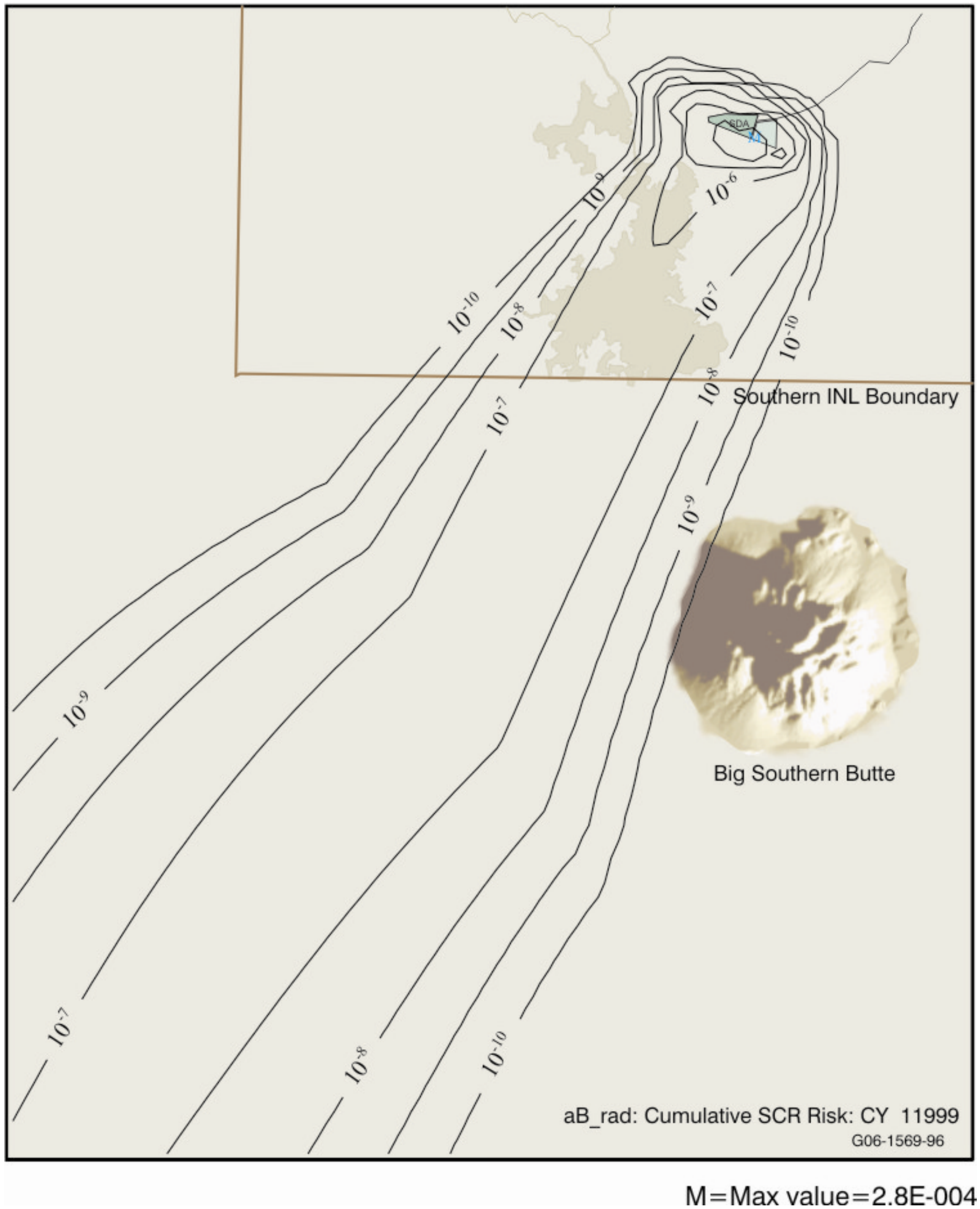


Figure E-24. Peak groundwater risk isopleths for radionuclides at the end of the 10,000-year groundwater simulation period for the regional refined grid.

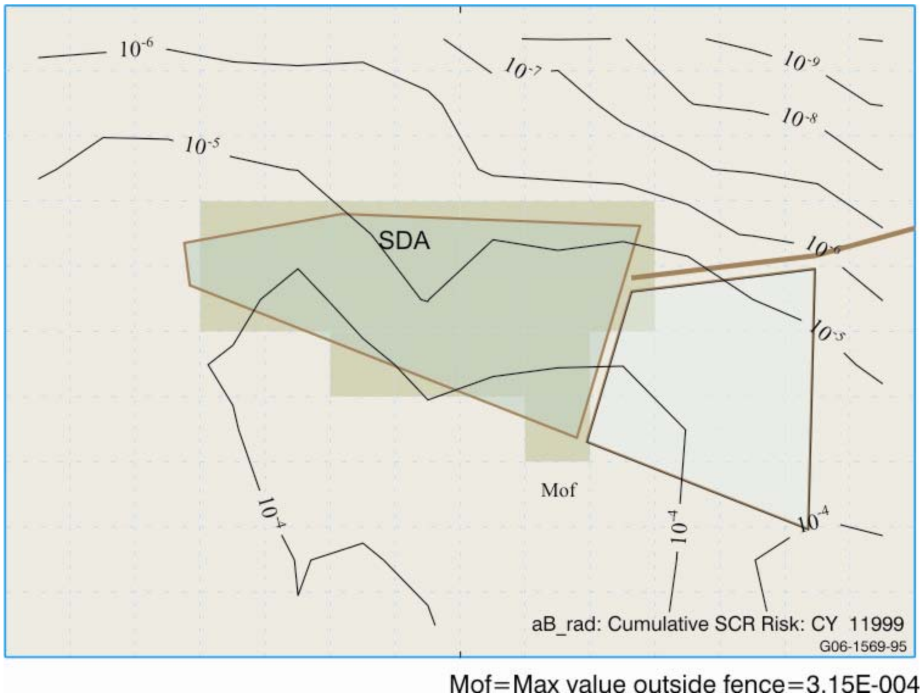


Figure E-25. Peak cumulative groundwater risk isopleths for radionuclides at the end of the 10,000-year groundwater simulation period for the local refined grid.

E-1.2.3 Bases for the Feasibility Study

According to an assumption in the Second Addendum (Holdren and Broomfield 2004) remedial action will be implemented for Operable Unit 7-13/14 if risk estimates exceed threshold values or simulated aquifer concentrations exceed MCLs. As demonstrated by the modeling and baseline risk assessment presented in this RI/BRA, these conditions are identified; therefore, a feasibility study will be prepared to evaluate remedial alternatives. The Operable Unit 7-13/14 feasibility study should focus on remedial alternatives that address the primary COCs identified in Tables E-1 and E-2.

Source-term information developed through records research, geophysical surveys, inventory reconstruction, and mapping have proven reliable through probing and retrieval demonstrations. This information, in conjunction with risk estimates, provides a good foundation for the feasibility study. As described in Table E-3, high densities of fission- and activation-product COCs generated through reactor operations at the INL Site (i.e., C-14, Tc-99, I-129, and Sr-90) are located primarily in trenches and soil vaults. Conversely, Rocky Flats Plant-generated COCs—VOCs, nitrate, and actinides including Am-241, plutonium isotopes, and their long-lived progeny (i.e., Ra-226, Ra-228, and Pb-210)—are located mostly in pits. Roughly half of the total nitrate in the SDA is located on Pad A. Both INL Site- and Rocky Flats Plant-generated COCs contribute to surface exposure pathway risk. Groundwater pathway primary COCs include VOCs and nitrate, which originated at the Rocky Flats Plant, and Tc-99 and I-129, which originated at the INL Site. Secondary groundwater pathway COCs are long-lived decay-chain actinides associated with Rocky Flats Plant waste: Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. Most of the waste producing these decay-chain progeny is located in pits, though a sizable fraction of uranium-related waste is on Pad A.

Preliminary remediation goals should be defined for primary COCs. Goals for surface exposure pathways should be predicated on reducing exposure-point concentrations (e.g., concentrations in soil and air) to protective levels. Remediation goals for the groundwater pathway should be based, at least in part, on anticipated performance of the surface barrier. The surface barrier is an element of final remediation for Operable Unit 7-13/14 because DOE, DEQ, and EPA recognize the impracticality of returning the SDA to a pristine state. A surface barrier is required to address contamination remaining at the site in two ways: (1) limiting infiltration and consequent transport downward through the vadose zone and aquifer and (2) inhibiting transport upward to the surface by plants and burrowing animals.

Simulations showing gross overpredictions (up to three orders of magnitude) of vadose zone and aquifer concentrations for Tc-99 and I-129 (see Section 5.2.5) should be refined before preliminary remediation goals are established for the feasibility study. These contaminants are modeled as highly mobile (i.e., with a distribution coefficient of 0 mL/g), which is based on current literature; however, monitoring data clearly refute rapid release from the source. Rather than assuming that these contaminants are available for immediate release through surface washoff, slower release through distributed container failure should be evaluated. Initial research indicates that many waste forms containing Tc-99 and I-129 were buried in welded stainless steel containers. If sufficient information can be collected to support a new model run for the feasibility study, a revised feasibility study baseline should be developed for Tc-99 and I-129.

Modeling and risk assessment for trichloroethylene should be refined early in development of the feasibility study to confirm that trichloroethylene is a COC and to provide a better basis for defining preliminary remediation goals. Trichloroethylene was semiquantitatively evaluated in the RI/BRA by scaling its inventory against carbon tetrachloride to estimate risk. Trichloroethylene is an organic solvent contained primarily in Rocky Flats Plant Series 743 sludge and is largely collocated with carbon tetrachloride.

Secondary COCs are defined based on the 10,000-year simulation period. Secondary COCs should not be direct targets for focused analysis of alternatives in the feasibility study (e.g., no preliminary remediation goals or additional grout case for actinides), but the long-term effectiveness of all assembled alternatives for these COCs should be evaluated and presented in the feasibility study. The feasibility study should include a sensitivity case to show that grouting would not effectively address secondary COCs in the far future. In addition, the feasibility study should evaluate the effectiveness of a surface barrier (assumed to be effective indefinitely) and retrieval (which is scalable to any size for targeted waste forms) in reducing long-term risk for these secondary COCs. Secondary COCs also should be identified as analytes for environmental monitoring to expedite periodic review of their status and to ensure that remedies are protective.

E-1.2.4 Remedial Action Objectives

As indicated in the Second Addendum (Holdren and Broomfield 2004), the feasibility study will be based on the assumption that source-term control will sufficiently reduce risk. Methods to mitigate contaminants that have already been released will not be evaluated in the Operable Unit 7-13/14 feasibility study, except to address continued operation of the vapor vacuum extraction system. Based on this assumption, remedial action objectives for Operable Unit 7-13/14 are provided in the Second Addendum and remain appropriate for developing the feasibility study. The only modifications are to replace the ABRA with this RI/BRA as the basis and to reduce the cumulative hazard index from 2 to 1. The first two remedial action objectives are related to risk thresholds. The last three objectives express the fundamental assumption that remedial action at the SDA will include an engineered surface barrier. Remedial action objectives are:

- Limit cumulative human health cancer risk for all exposure pathways to less than or equal to 1E-04
- Limit noncancer risk for all exposure pathways to a cumulative hazard index of less than 1 for current and future workers and future residents
- Inhibit migration of COCs, as identified in the RI/BRA, into the vadose zone and the underlying aquifer
- Inhibit exposures of ecological receptors to COCs in soil and waste with concentrations greater than or equal to 10 times background values and with a hazard quotient greater than or equal to 10
- Inhibit transport of COCs to the surface by plants and animals.

E-1.3 References

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ACRONYMS

ABRA	Ancillary Basis for Risk Analysis
ARA	Auxiliary Reactor Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
COC	contaminant of concern
DEQ	(Idaho) Department of Environmental Quality
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
EDTA	ethylenediaminetetraacetic acid
EPA	U.S. Environmental Protection Agency
FFA/CO	Federal Facility Agreement and Consent Order
FY	fiscal year
GEOPS	Geologic and Environmental Probe System
HEPA	high-efficiency particulate air
ICP	Idaho Cleanup Project
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology Engineering Center
IRA	Interim Risk Assessment
LLW	low-level waste
MCL	maximum contaminant level
NRF	Naval Reactors Facility
OCVZ	Organic Contamination in the Vadose Zone
RBC	risk-based concentration (for soil)
RCRA	Resource Conservation and Recovery Act
RI/BRA	remedial investigation and baseline risk assessment
RI/FS	remedial investigation and feasibility study
ROD	record of decision
RTC	Reactor Technology Complex
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SVR	soil vault row
TAN	Test Area North
TRU	transuranic
TSA	Transuranic Storage Area
USGS	U.S. Geological Survey
VOC	volatile organic compound
WIPP	Waste Isolation Pilot Plant

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FIGURES

1. INTRODUCTION

Site characteristics and estimated cumulative risks associated with Operable Unit 7-13/14 at the Idaho National Laboratory (INL) Site[a] are presented in this remedial investigation and baseline risk assessment (RI/BRA). The RI/BRA assesses potential risk to human health and the environment in the absence of any further remedial action at the INL Radioactive Waste Management Complex (RWMC). The RI/BRA focuses almost exclusively on the Subsurface Disposal Area (SDA), a radioactive waste landfill within RWMC.

Operable Unit 7-13/14 is defined as the comprehensive remedial investigation and feasibility study (RI/FS) for RWMC. The RI/FS is being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC § 9601 et seq., 1980) under framework provided in the INL-specific Federal Facility Agreement and Consent Order (FFA/CO) (DOE-ID 1991). This RI/BRA is identified as an FFA/CO primary document (DOE 2002) and was prepared in accordance with U.S. Environmental Protection Agency (EPA) RI/FS guidance (EPA 1988).

Analysis presented in this report evaluates baseline risk (i.e., risk to human health and the environment in the hypothetical absence of any remedial action). The human health risk assessment identifies 18 primary and eight secondary contaminants of concern (COCs) for Operable Unit 7-13/14 for a total of 26 COCs (i.e., 20 radionuclides and six chemicals). Primary COCs are identified based on risk and simulated groundwater concentrations within a 1,000-year timeframe, while secondary COCs are identified based on simulated groundwater ingestion risk within 10,000 years. Primary COCs are Am-241, C-14, Cs-137, I-129, Pb-210, Pu-239, Pu-240, Ra-226, Ra-228, Sr-90, Tc-99, Th-228, carbon tetrachloride, 1,4-dioxane, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene. Secondary COCs are Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. The ecological risk assessment identifies 10 radionuclides and three chemical ecological COCs: Am-241, Cs-137, Pu-238, Pu-239, Pu-240, Pu-241, Ra-226, Sr-90, U-234, U-238, beryllium, cadmium, and lead. Site characteristics and risk assessment details that underlie identification of these COCs are presented in the body of this report.

1.1 Purpose

This RI/BRA will provide the U.S. Department of Energy (DOE), the Idaho Department of Environmental Quality (DEQ), and the EPA with a basis for determining whether additional remedial action at RWMC is necessary. Information in this RI/BRA will support future risk management decisions for Waste Area Group 7 under CERCLA and the FFA/CO.

1.2 Scope

This RI/BRA incorporates relevant information from previous investigations and studies to assess risk conducted for Waste Area Group 7. The evaluation is cumulative and comprehensive, meaning that additive risks for all contaminants and exposure pathways were considered, and that all sources of risk at the SDA were analyzed to evaluate the overall risk potential.

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a. In 2005, the Idaho National Engineering and Environmental Laboratory was renamed the INL Site, and management was split into two contracts: INL and Idaho Cleanup Project (ICP). The INL contract is managed by Battelle Energy Alliance and includes reactor design and development, nonnuclear energy development, materials testing and evaluation, and national security. The ICP contract is managed by CH2M-WG Idaho, LLC, and includes operational safety, radioactive waste management, and environmental restoration.

Primary elements of RI/BRA scope include:

- Assessing the nature and extent of contamination associated with Waste Area Group 7
- Evaluating current and future cumulative and comprehensive risks posed by Waste Area Group 7 to identify human health and environmental COCs.

The RWMC comprises (1) the SDA, which contains buried waste; (2) the Transuranic Storage Area (TSA), which contains waste stored above ground; and (3) an administration and operations area, with various support facilities. Quantitative analysis in this RI/BRA is limited to waste buried in the SDA. Risk potential associated with the TSA and support facilities will be evaluated in the future, after disposition of all stored waste is complete and the TSA is closed.

1.3 Schedule

Signing agencies of the FFA/CO (i.e., DOE, DEQ, and EPA) have modified scope and schedule for Operable Unit 7-13/14 several times since the FFA/CO was finalized in 1991. Modifications were predicated on the magnitude, complexity, and duration of the project; agreements to accommodate modified scope and schedule for the Operable Unit 7-10 interim action for Pit 9 (DOE-ID 1998a; DOE 2002); and a non-time-critical removal action to retrieve waste from Pit 4 (DOE 2004).

Originally, scope and schedule for Operable Unit 7-13/14 were outlined in the first Scope of Work (Huntley and Burns 1995), and details were developed in the original Operable Unit 7-13/14 RI/FS Work Plan (Becker et al. 1996). In 1997, DOE, DEQ, and EPA collaborated to revise the Scope of Work (INEEL 1997) and to develop the first Addendum to the Work Plan (DOE-ID 1998b). The schedule for delivering the draft RI/FS for DEQ and EPA review under the FFA/CO was modified from September 1997 to March 2002.

The Operable Unit 7-13/14 schedule was extended again to accommodate additional changes related to the Pit 9 interim action, in accordance with the April 16, 2002, Agreement to Resolve Disputes (DOE 2002). As a result of the agreement, the draft RI/BRA for Operable Unit 7-13/14 was reclassified from a secondary to a primary document under the FFA/CO and scheduled for submittal to DEQ and EPA with an enforceable deadline of August 2005. The enforceable deadline for the associated draft feasibility study, also a primary document, was rescheduled to December 2005. The Second Revision to the Scope of Work (Holdren and Broomfield 2003) and the Second Addendum to the Work Plan (Holdren and Broomfield 2004) were developed through collaboration among DOE, DEQ, and EPA to document the revised schedule and to modify scope for Operable Unit 7-13/14.

The most recent schedule extension was formalized by DOE, DEQ, and EPA to delay the Operable Unit 7-13/14 RI/FS while proceeding with retrieval of targeted waste from a portion of Pit 4 (DOE 2004). The enforceable schedules for submitting the draft RI/BRA and feasibility study to DEQ and EPA review were changed to August 2006 and December 2006, respectively; however, the Operable Unit 7-13/14 Scope of Work and Work Plan were not revised because tasks required to support development of the RI/FS were not formally modified.

1.4 Regulatory Background

In January 1986, hazardous waste disposal sites at the INL Site that could pose unacceptable risks to health, safety, or the environment were identified in an INL installation assessment report (INEL 1986). Sites were ranked using either the EPA hazard ranking system for sites with chemical contamination or the DOE-modified hazard ranking system for radioactively contaminated sites. A score of 28.5 or higher in either category qualified a site for inclusion on the National Priorities List (54 FR 48184, 1989). Because several sites within the INL Site received scores greater than 28.5, the entire reservation became a candidate for the National Priorities List. The RWMC received a modified hazard ranking system score of 9.0 and a hazard ranking score of 9.0 based on the large quantities of waste and their radiological, chemical, and physical characteristics.

On July 10, 1987, the DOE Idaho Operations Office entered into a Consent Order and Compliance Agreement with Region 10 of the EPA and the U.S. Geological Survey (DOE-ID 1987). The agreement called for implementing an action plan to remediate active and inactive waste disposal sites at the INL Site under authority of the Resource Conservation and Recovery Act (RCRA) (42 USC § 6901 et seq., 1976). Generation, transportation, treatment, storage, and disposal of hazardous waste are regulated by RCRA. Sites identified for further evaluation during the INL installation assessment, including those located within RWMC, were covered by the 1987 agreement.

On November 15, 1989, the EPA added the INL Site to the National Priorities List under CERCLA, also known as the Superfund. High-priority sites for investigation and remediation of hazardous materials are identified in the National Priorities List. The decision to add the INL Site to the National Priorities List was based on detection of contaminants in the environment at the INL Site. A requirement of CERCLA is providing members of the public with opportunities to participate in the decision-making process.

The FFA/CO and its attached Action Plan (DOE-ID 1991) were negotiated and signed by DOE Idaho, EPA, and the State of Idaho to implement remediation of the INL Site under CERCLA. Effective December 4, 1991, the FFA/CO superseded the Consent Order and Compliance Agreement. The goals of the FFA/CO are to ensure that (1) potential or actual INL releases of hazardous substances to the environment are thoroughly investigated in accordance with the National Contingency Plan (40 CFR 300) and (2) appropriate response actions are taken to protect human health and the environment. The FFA/CO established the procedural framework and schedule for developing, prioritizing, implementing, and monitoring response actions at the INL Site in accordance with CERCLA and RCRA legislation and the Idaho Hazardous Waste Management Act (IDAPA 58.01.05). The FFA/CO is consistent with a general approach approved by EPA and DOE in which agreements with states as full partners would allow site investigation and cleanup to proceed using a single “road map” to minimize conflicting requirements and to maximize limited remediation resources. For management purposes, the FFA/CO divided the INL Site into 10 waste area groups. Waste Area Group 7, comprising RWMC, is located in the southwestern quadrant of the INL Site. Figure 1-1 shows the INL Site with locations of RWMC and other major INL Site facilities. Figure 1-2 provides a map of RWMC showing the SDA, the TSA, and the administration and operations area.

The FFA/CO Action Plan further divided the environmental site investigation at Waste Area Group 7 into many operable units. In the standard FFA/CO RI/FS process, potential source areas (sites) within each waste area group were assigned to an operable unit for investigation or remedial activities. This process was designed to match the rigor of the assessment process with the complexity of each individual site and to allow for flexibility in determining appropriate further action as an assessment or action is completed; however, in addition to operable units defined as specific release sites, several operable units within Waste Area Group 7 were defined as contaminant exposure pathways (e.g., air pathway and vadose zone pathway).

The RI/FS for Operable Unit 7-13, transuranic (TRU) pits and trenches, was established to investigate only those portions of the SDA containing buried TRU radionuclides. The Operable Unit 7-14 comprehensive RI/FS was designated as the final, cumulative investigation of Waste Area Group 7. Subsequently, however, Operable Unit 7-13 and Operable Unit 7-14 were combined into the single Operable Unit 7-13/14, and now the comprehensive RI/FS for Waste Area Group 7 includes the TRU pits and trenches (Huntley and Burns 1995).

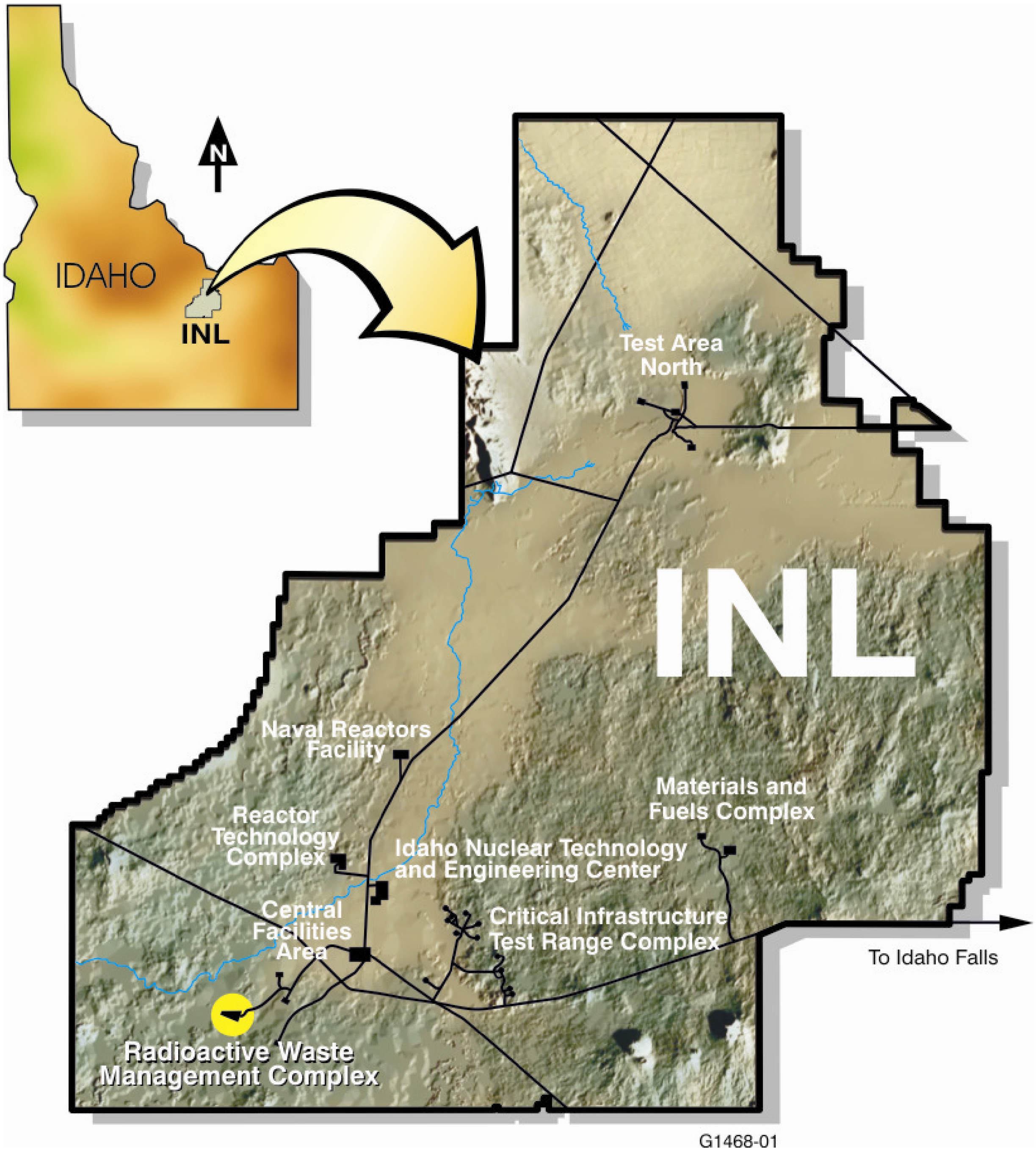

Figure 1-1. Idaho National Laboratory Site.

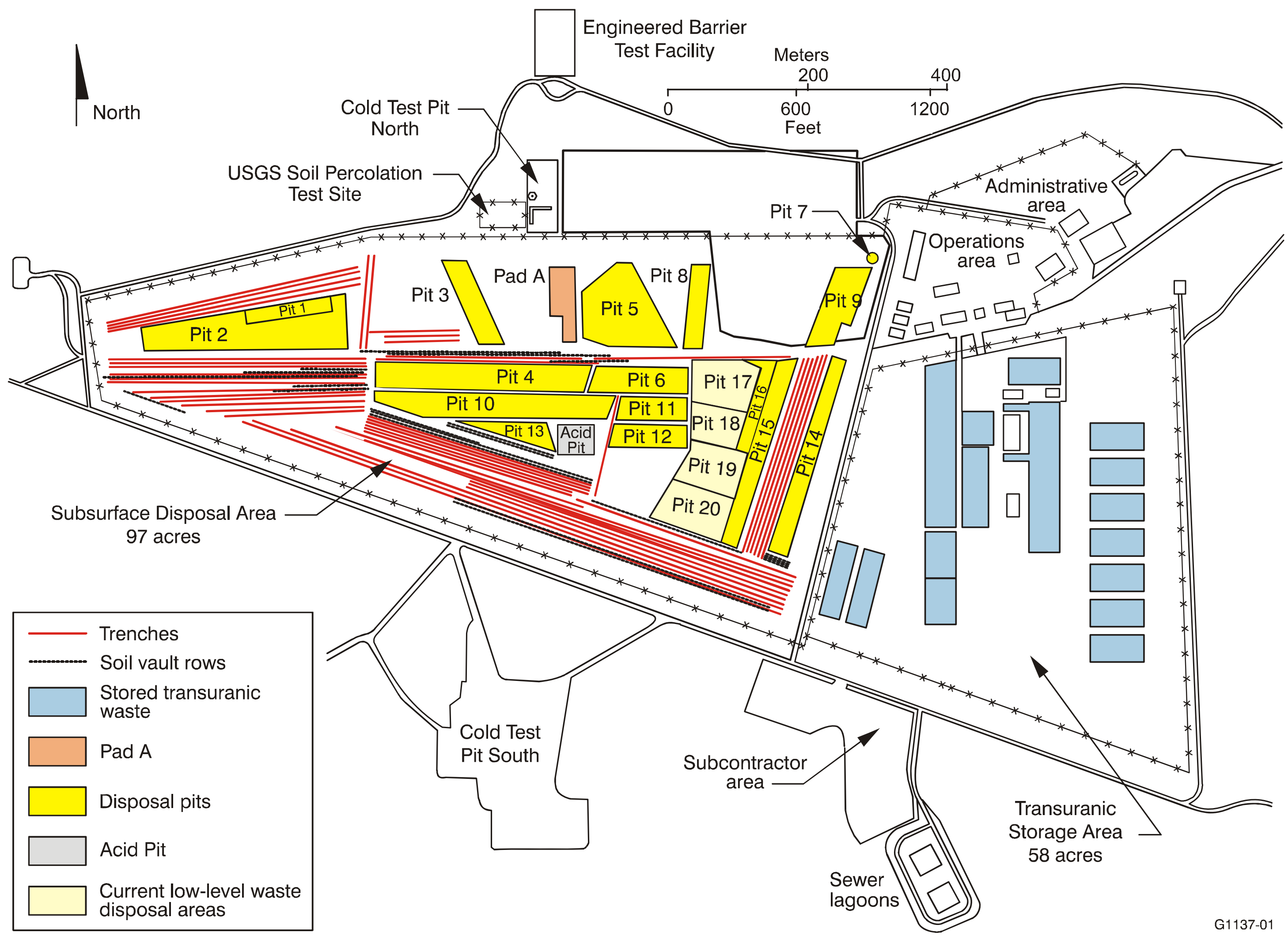

Figure 1-2. Radioactive Waste Management Complex.

1.5 Report Organization

This RI/BRA contains eight sections. Individual sections conclude with references cited in that section, and a master reference list comprises the last section of the report. In addition, numerous supporting documents are available in the Administrative Record.[b] The report format is adapted from the outline suggested in EPA (1988) for remedial investigations. A summary of each section follows:

- Section 1 presents introductory information for the RI/BRA.
- Section 2 describes the INL Site and RWMC, including general historical background and physical characteristics (e.g., topography, meteorology, geology, hydrology, demography, and ecology).
- Section 3 provides a synopsis of RWMC operational history and describes studies used to assess Waste Area Group 7 under CERCLA and the FFA/CO.
- Section 4 addresses the nature and extent of contamination at Waste Area Group 7 and provides descriptions of waste and results of environmental monitoring.
- Section 5 presents simulations of contaminant release from buried waste and migration in the environment. Release mechanisms, routes of migration, persistence of contaminants in environmental media, and transport mechanisms are discussed. Results from source-term modeling are applied to transport simulations to estimate potential contaminant concentrations in environmental media. A conceptual site model also is presented.
- Section 6 presents the baseline risk assessment. Deterministic risks are estimated for five human health exposure scenarios: current occupational, current residential (at the INL Site boundary), future occupational, future residential (at the SDA boundary), and future agricultural well-driller (within the SDA). Also presented are exposure assessments, media concentrations, exposure quantification, toxicity assessment and risk characterization, and uncertainties in analysis. A limited analysis of current and future ecological risks also is presented.
- Section 7 summarizes the RI/BRA, identifies COCs, discusses data limitations, reiterates remedial action objectives, and presents recommendations for the feasibility study.
- Section 8 provides a master list of the references cited in Sections 1 through 7.

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b. The Administrative Record is a collection of project documents and is maintained in accordance with CERCLA. The official Administrative Record is located at the INL Technical Library in Idaho Falls, Idaho. Copies of documents in the Administrative Record are located in Idaho information repositories in the Boise INL Office, the Marshall Public Library in Pocatello, the Shoshone-Bannock Library in Fort Hall, and online at http://ar.inel.gov.

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